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16. ABSTRACT

The catalog of Industrial Process Profiles for Environmental Use was developed as an aid in defining the environmental impacts of industrial activity in the United States. Entries for each industry are in consistent format and form separate chapters of the study. The Plastics and Resins Industry includes operations which convert monomer or chemical intermediate materials obtained from the Basic Petrochemicals Industry and the Industrial Organic Chemicals Industry into resinous polymer products. Fabrication is not included in this industry, nor is blending or formulation of resin materials. This chapter provides an overview of the plastics and resins industry through a summary of information from the open literature describing industrial practice. Because of the wide range and complexity of the industry, this treatment necessarily describes only the more important processes and products. This type of summary eliminates many of the complexities and variations in processing, resulting in a somewhat simplified picture of the industry. Twenty process flow sheets and sixty process descriptions have been prepared to characterize the industry. Within each process description available data have been presented on input materials, operating parameters, utility requirements and waste streams. Data related to the subject matter, including company, raw material and product data, are included as appendices.

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Resins	Solid Waste Control	11I
Monomers	Organic Chemicals	
Resin Polymers	Chemical Industry	
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FOR ENVIRONMENTAL USE
CHAPTER 10
PLASTICS AND RESINS INDUSTRY

by

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PLASTICS AND RESINS INDUSTRY

INDUSTRY DESCRIPTION

The Plastics and Resins Industry includes operations which convert monomer or chemical intermediate materials obtained from the Basic Petrochemicals Industry and the Organic Chemicals Industry into resinous polymer products. Fabrication is not included, nor is blending or formulation of resin materials. Figure 1 is a simplified diagram showing the interrelation of closely related industries to the plastics and resins industry. There are eighteen operations treated in this report which were deemed significant in characterizing the industry: Mass Addition Polymerization, Emulsion Addition Polymerization, Suspension Addition Polymerization, High Pressure Mass Polymerization, Solution Polymerization, Particle Form Polymerization, Polyolefin Production (Ziegler), Phenolic Resin Production, Amino Resin Production, Polycarbonate Production, Epoxy Resin Production, Unsaturated Polyester Resin Production, Alkyd Resin Production, Poly(ethylene terephthalate) Production, Nylon 6 Resin Production, Nylon 66 Resin Production, Polyurethan Foam Production, Polyamide Resin Production, Poly (phenylene sulfide) Production, and Polyacetal Production. Each of these operations is represented by a flow sheet indicating processing sequence, waste streams, raw materials, and products. Table 1, a listing of products and the operations and processes in which they are made, is included as an aid to finding particular products considered in this treatment.

The 1972 Census of Manufacturers lists 323 establishments involved in Plastics and Resins manufacture employing 54,800 people. A 1974 estimate included in an EPA document indicates 300 producers operating over 400 plants. The 1974 employment figure is almost certainly proportionally higher also.

The total production of plastics and resins for 1974 was 10 Tg (22 billion lb), a 20 percent decrease from 1974 production levels. Because the Plastics and Resins Industry is sensitive to domestic economic conditions, and because the industry is linked to oil-derived raw materials, a feedstock shortage and a resulting slump have been encountered. It is difficult to accurately describe significant growth trends within the industry. Many economists expect feedstock shortages to continue but to become less intense. An industry economist predicts a recovery from the slump with a 7 to 9 percent average growth rate through 1980 due to increased prices in competitive materials.

Geographic locations are dictated by two factors: markets and raw materials. Producers of large volume resins such as poly(vinyl chloride), polystyrene, and the polyolefins which are generally produced in large continuous operations are usually located near petrochemical complexes on the Gulf Coast because of their dependence on large quantities of raw materials. The producers of small amounts of resins for particular end uses are usually more market oriented and as a result are likely to be located in large population areas.

The 1972 Census of Manufacturers indicates that the bulk of the electrical power consumed in this industry is purchased. In 1971, 6358.4 GWh were purchased, while 411.9 GWh were generated for use within the plastics and resins industry. The total energy consumed for heat and power, including fuel and electrical consumption, was 45.7 TWh equivalents in 1971.

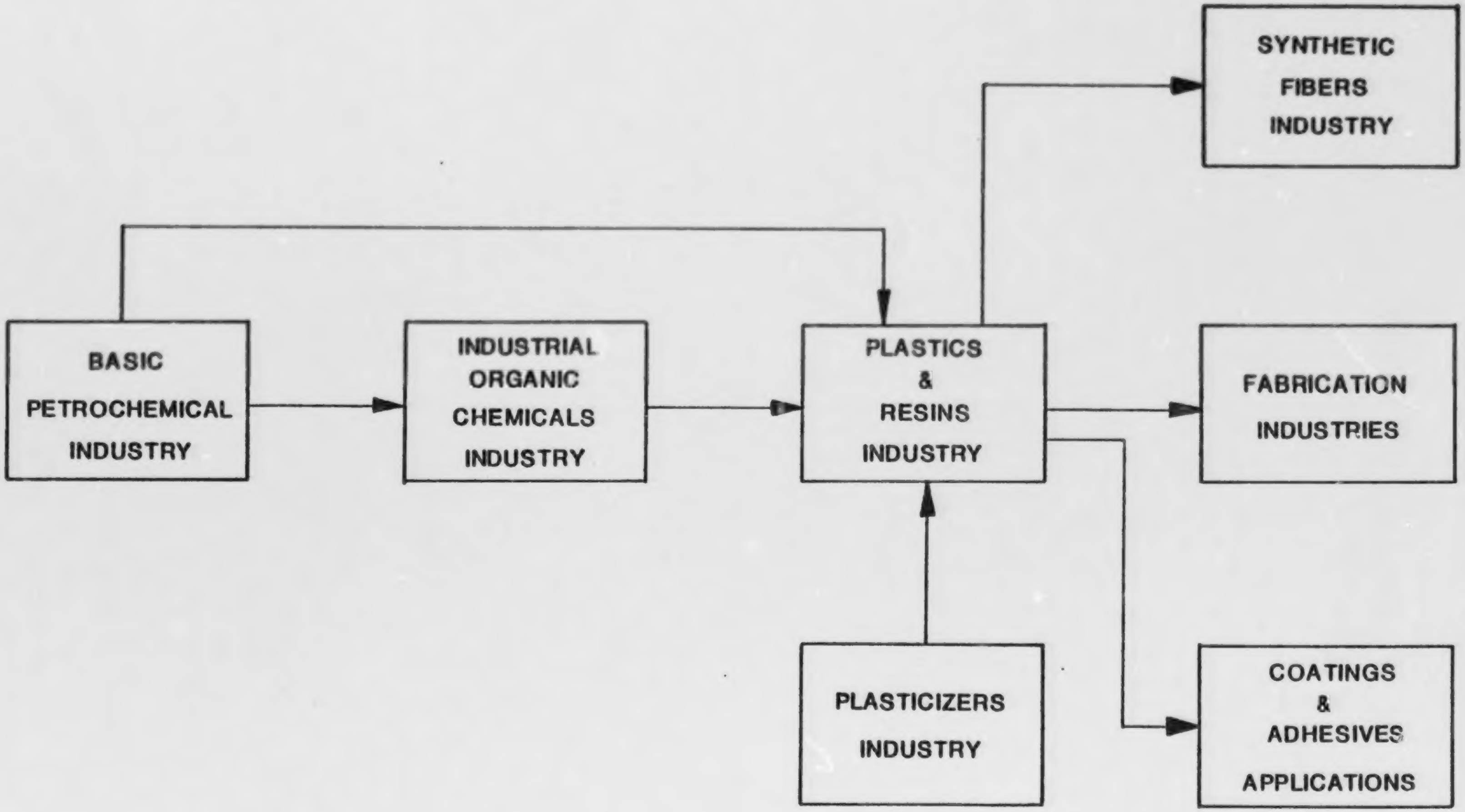
BASIC PETROCHEMICAL INDUSTRY
INDUSTRIAL ORGANIC CHEMICALS INDUSTRY
PLASTICS & RESINS INDUSTRY
PLASTICIZERS INDUSTRY
SYNTHETIC FIBERS INDUSTRY
FABRICATION INDUSTRIES
COATINGS & ADHESIVES APPLICATIONS

FIGURE 1. INTERRELATION OF INDUSTRIES WITH THE PLASTICS AND RESINS INDUSTRY

Table 1. OPERATIONS AND PRODUCTS OF THE PLASTICS AND RESINS INDUSTRY

Operation	Products	Process Numbers
Mass Addition Polymerization	Polystyrene	1, 2, 3
	Acrylonitrile-butadiene-styrene	
	Styrene-acrylonitrile	
	Methyl methacrylate	
	Allyl resins	
Emulsion Addition Polymerization	Latices	4, 5
	Polystyrene	
	Acrylonitrile-butadiene-styrene	
	Styrene-acrylonitrile	
	Poly(vinyl chloride)	
	Poly(vinyl acetate)	
	Poly(vinylidene chloride)	
	Polyalkyl acrylates and copolymers	
	Polyalkyl methacrylates and copolymers	
	Poly(vinyl esters) and copolymers	
	Polyacrylonitrile	
	Polybutadiene	
	Polychloroprene	
	Polyisoprene	
	α-Methylstyrene copolymers	
	Isobutylene copolymers	
	Solids	
	Poly(vinyl chloride) plastisol resins	
	Styrene-acrylonitrile graft polyblends with synthetic rubbers	
	Teflon (polytetrafluoro ethylene)	
	Kel-F (polytrifluorochloroethylene)	

Table 1 (Continued). OPERATIONS AND PRODUCTS OF THE PLASTICS AND RESINS INDUSTRY

Operation	Products	Process Numbers
Suspension Addition Polymerization Processes	Polymethacrylic esters and copolymers	6, 7, 8
	Polyacrylic esters and copolymers	
	Polystyrene	
	Rubber-modified polystyrene	
	Poly(vinylidene chloride)-vinyl chloride copolymers	
	Poly(vinyl chloride) and copolymers	
	Poly(vinyl acetate)	
	Styrene acrylonitrile	
	Rubber-modified styrene-acrylonitrile copolymers (ie. ABS and others)	
	Polydivinyl benzene and copolymers	
	Polytrifluorochloroethylene	
High Pressure Mass Polymerization	Low density polyethylene	9, 10, 11
Solution Polymerization	Styrene polymers and copolymers	12, 13
	α-Methylstyrene copolymers	
	Polyacrylic acid	
	Polymethacrylic acid	
	Polyacrylamide	
	Poly(vinyl pyrrolidone) and copolymers	
Particle Form Polymerization (Polyethylene)	Polyethylene	14, 15
	Ethylene-olefin copolymers	
Polyolefins Polymerization (Ziegler)	High density polyethylene	16, 17, 18
	Polypropylene	
	Polybutene	
	(Various copolymers)	

Table 1 (Continued). OPERATIONS AND PRODUCTS OF THE PLASTICS AND RESINS INDUSTRY

Operation	Products	Process Numbers
Phenolic Resin Production	Resols Novolaks	19, 20, 21, 22
Amino Resin Production	Amino Resins	23, 24, 25
Polycarbonate Production	Polycarbonates (linear thermoplastic polyesters)	26, 27, 28, 29, 30
Epoxy Resin Production	Epoxy resins	31, 23, 33, 34
Unsaturated Polyester Resin Production	Polyester resins (Mixtures of unsaturated polyester resin and vinyl-type monomers)	35, 36
Alkyd Resin Production	Alkyd Resins	37, 38
Polyethylene Terephthalate Production	Polyethylene terephthalate	39, 40, 41
Nylon 6 Production	Nylon 6	42, 43, 44
Nylon 66 Production	Nylon 66	45, 46, 47, 48, 49, 50
Polyurethan Foam Production	Polyurethan foam	51, 52, 53
Polyamide Resin Production	Polyamide resins	54, 55
Poly (phenylene sulfide) Production	Poly (phenylene sulfide)	56, 57
Polyacetal Production	Polyacetal resins	58, 59, 60

Raw Materials

Major feed materials for this industry are obtained from the basic petrochemicals industry and from the industrial organic chemicals industry. The progression of materials from petrochemicals to plastics is illustrated in Figure 2 for eight high-volume production resins.

In addition to hydrocarbon feedstocks the industry employs many additives such as fillers, pigments, fire retardants, and plasticizers to produce a final resin product. A raw materials list was compiled from the process descriptions in this chapter and may be found in Appendix A, Table A-1. While there are omissions due to incomplete coverage of the industry, the list is thought to be representative of the substances in common use for making plastics and resins. Extensive lists of antioxidants, antistatic agents, flame retardants, free radical initiators, and colorants are also included in Appendix A along with a list of their manufacturers and suppliers. A list of plasticizers may be found in the product list of the Synthetic Plasticizers Industry (Chapter 13).

The 1972 Census of Manufacturers lists materials consumed by the plastics and resins industry. Those raw materials deemed important enough for reporting by the Bureau of Census are listed in Table 2.

Products

The plastics and resins industry as defined in this treatment produces solid materials to be molded, cast, or extruded by fabricators and solutions, pastes, and emulsions for coatings and adhesives. There are almost limitless numbers of possible products made with different formulations and additives. The largest consumers of plastics and resins products are the building and construction industries and the packaging industries. They consume about 45 percent of the resins production.

There are two general types of polymeric materials produced in this industry: thermosetting and thermoplastic resins. Thermoplastics, materials whose shape and form are reversible by the application of heat, accounted for about 85 percent of the plastics production in 1975. Thermosetting materials, those whose form is not reversible when set by heat, accounted for the remainder. Table 3 lists the largest volume production materials with production data for 1974 and 1975. These products approximate 90 percent of the total plastics industry production. A complete product list is included in Appendix B.

Companies

The industry is composed of an estimated 300 plastics producers. Although an analysis of the large producers was prevented by lack of capacity and production data, Table 4 lists twenty-four companies termed major producers in one source of information.

Table 2. MAJOR RAW MATERIALS FOR THE PLASTICS AND RESINS INDUSTRY

Raw Materials	1972 Consumption
acrylates and methacrylates, monomers	358.4 Gg (789.5 x 10^6 lb)
acrylonitrile	124.4 Gg (274.1 x 10^6 lb)
alcohols (except ethyl)	1.86 hm^3 (490.4 x 10^6 gal)
carbon black	Not reported
cellulose acetate	Not reported
extender oils (petroleum derived)	Not reported
formaldehyde (37%)	618.4 Gg (1362.2 x 10^6 lb)
glycerin	11.8 Gg (26.1 x 10^6 lb)
liquid refinery and petroleum gases	
butadiene	156.4 Gg (344.6 x 10^6 lb)
ethylene	1.978 Tg (4,356.7 x 10^6 lb)
other (isoprene, propylene, isobutylene, etc.)	530.5 Gg (1168.5 x 10^6 lb)
melamine	23.0 Gg (50.7 x 10^6 lb)
phenol	285.7 Gg (629.2 x 10^6 lb)
phthalic anhydride	103.1 Gg (227.2 x 10^6 lb)
plasticizers	93.5 Gg (205.9 x 10^6 lb)
rubber processing chemicals (accelerators, antioxidants, blowing agents, inhibitors, peptizers, etc.)	Not reported
soap and detergents	18.1 Gg (39.9 x 10^6 lb)
sodium hydroxide	3.54 Gg (3.9 x 10^6 tons)
styrene	1.417 Tg (3122.2 x 10^6 lb)
sulfuric acid (100%)	81 Gg (90 x 10^3 tons)
thermoplastic resins	242.8 Gg (534.9 x 10^6 lb)
thermosetting resins	17.2 Gg (37.9 x 10^6 lb)
urea	157.5 Gg (346.9 x 10^6 lb)
vinyl acetate monomer	193.1 Gg (425.3 x 10^6 lb)
vinyl chloride monomer	1.176 Tg (2591.4 x 10^6 lb)
woodpulp (excluding wood flour)	40.0 Gg (44.1 x 10^3 tons)

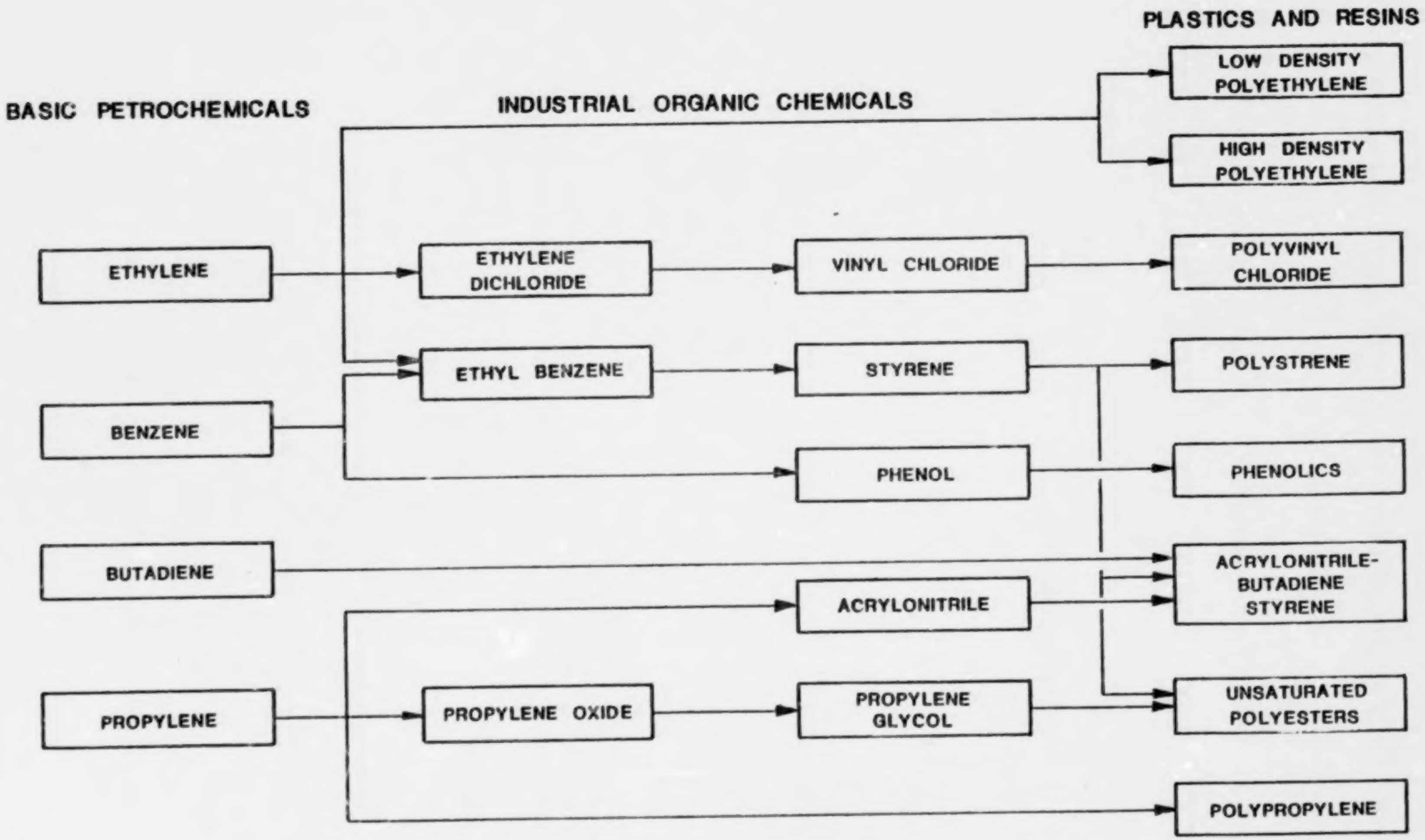
PLASTICS AND RESINS
BASIC PETROCHEMICALS
INDUSTRIAL ORGANIC CHEMICALS
LOW DENSITY POLYETHYLENE
HIGH DENSITY POLYETHYLENE
ETHYLENE
ETHYLENE DICHLORIDE
VINYL CHLORIDE
POLYVINYL CHLORIDE
ETHYL BENZENE
STYRENE
POLYSTRENE
BENZENE
PHENOL
PHENOLICS
BUTADIENE
ACRYLONITRILE-BUTADIENE STYRENE
ACRYLONITRILE
PROPYLENE
PROPYLENE OXIDE
PROPYLENE GLYCOL
UNSATURATED POLYESTERS
POLYPROPYLENE

FIGURE 2. PROGRESSION OF PETROCHEMICALS TO PLASTICS

Table 3. LARGE VOLUME PRODUCTS OF THE PLASTICS AND RESINS INDUSTRY

	1975 Tg (billion lbs)	1974 Tg (billion lbs)
THERMOPLASTIC RESINS		
polyethylene, low density	2.15 (4.74)	2.69 (5.93)
styrene and copolymers	1.82 (4.01)	2.15 (4.74)
poly(vinyl chloride) and copolymers	1.65 (3.64)	2.20 (4.85)
polyethylene, high density	1.11 (2.45)	1.29 (2.84)
polypropylene and copolymers	0.86 (1.90)	1.02 (2.25)
THERMOSETTING RESINS		
phenolic and other tar acids	0.48 (1.05)	0.608 (1.34)
polyesters (unsaturated)	0.38 (0.83)	0.41 (0.91)
urea resins	0.31 (0.69)	0.38 (0.84)
epoxies (unmodified)	0.09 (0.20)	0.11 (0.25)
melamine resins	0.055 (0.12)	0.073 (0.16)

Source: C & EN's Top 50 Chemical Products and Producers. Chemical and Engineering News. 54(19): 33-39, May 3, 1976.

Table 4. MAJOR PLASTICS PRODUCERS

Allied Chemical
Borden
Borg-Warner (Marbon)
Celanese
Dart
Diamond-Shamrock
Dow
Du Pont
Eastman Kodak
Ethyl
Foster Grant
B. F. Goodrich
Gulf
Hercules
Koppers
Monsanto
National Distillers
Phillips Petroleum
Shell
Standard Oil (Indiana)[a]
Standard Oil (New Jersey)[b]
Tenneco
Union Carbide
Uniroyal

[a] Amoco, subsidiary

[b] Now Exxon

Source: Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0266, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

1976 Directory of Chemical Producers

The list in Table 4 includes mostly oil companies integrated toward end products and chemical companies integrated back to raw materials as well as forward to end products. Many of the installations produce monomer, polymer, and fabricated end products at the same site. An estimated one-third of fabricated plastic items are manufactured by the resin producers, a fact which indicates the degree of forward integration within the industry. A complete list of companies is included in Appendix C with locations and capacities when available.

Environmental Impact

Gaseous emissions of hydrocarbon materials are encountered throughout this industry. Some of these organic compounds are toxic materials, notably vinyl chloride, toluene diisocyanate, phosgene, and pyridine. Great concern has been generated for the welfare of workers subjected to exposure to these substances, and maximum allowable concentration levels are being reassessed. Another point of concern regarding hydrocarbon emissions is the reaction of these substances in the atmosphere to form constituents of photochemical smog. Hydrocarbons vary in their degree of reactivity in atmospheric oxidation reactions depending on their chemical structure. Olefins are the most reactive followed by aromatics, paraffins, and naphthenes. The industry uses very large quantities of olefins and makes extensive use of aromatics and paraffins.

Solid wastes generated by this industry are landfilled or incinerated by the resin producers who generally maintain their own disposal systems. The waste originating from off-spec and excess product as well as from captured particulates and fines is recycled when possible. A quantity of 2.6 Tg/yr (5.8 billion lbs/yr) of plastic waste is recycled, while 0.77 Tg/yr (1.7 billion lbs/yr) end up as waste. This is compared to 3.8 Tg/yr (8.3 billion lbs/yr) of non-industrial plastic waste generated for which recycle technology is lacking. To put the solid waste problem in perspective, the total solid waste generated in one year in the U. S. is about 272 Tg (300 million tons).

Incineration of plastics may cause some emissions of gaseous pollutants depending on the chemical composition of the polymer materials. Some of the problems of this nature which have been encountered are HCl production from poly(vinyl chloride) incineration; NOx production from burning nylon resins; and thick, dense smoke evolution when polystyrene is burned in an air atmosphere.

Liquid waste streams, generally aqueous, are also encountered throughout the industry. Much of the wastewater orginates from processing in which the process streams are in direct contact with water. Waste water may also be formed during the course of a chemical reaction; it may arise from cleaning process vessels, area housekeeping, utility boiler and cooling water blowdown, and other sources such as laboratories. The contaminants encountered in the waste water include organic reactants, monomers, oligomers, polymers, and salts.

EPA studies to suggest guidelines for effluent limitations for the industry established four major subcategories with respect to waste water characteristics. These subcategories are presented in Table 5.

Table 5. **MAJOR WASTE-WATER** SUBCATEGORIES OF THE PLASTICS AND RESINS INDUSTRY

Major Subcategory	Raw Waste load BOD5 Value[a]	Achievable BOD5 Value
I	low	<20 mg/liter
II	high	<20 mg/liter
III	low or high	30 - 75 mg/liter
IV	low or high	>75 mg/liter

[a] <10 kg/Mg product is low; >kg/Mg product is high.

Products found in each category are listed in Table 6, although all of the **products are not treated** in this report.

Table 6. PRODUCT CLASSIFICATION BY WASTE-WATER CHARACTERISTICS

Category	Products
I	ethylene vinyl acetate, polytetrafluoroethylene, polypropylene fiber, poly(vinylidene chloride), poly(vinyl chloride), poly(vinyl acetate), polystyrene, polyethylene, polypropylene
II	acrylic resins, cellulose derivatives, ABS/SAN, cellophane, rayon
III	alkyd resins, unsaturated polyesters, cellulose nitrate, polyamides, saturated polyesters, poly(vinyl butyral), poly(vinyl ethers), silicones, nylon 66, nylon 6, and cellulose acetates
IV	nitrile barrier resins, spandex fibers, acrylics

The extensive heating and cooling requirements necessitate elaborate cooling tower, refrigeration, and steam generation facilities. The waste water streams from these points are generally combined to be sent to the water treatment plants. Cooling tower and boiler blowdown streams may contain toxic anti-corrosion chemicals such as chromium compounds and anti-fouling agents.

Specific emissions problems for resin products are indicated in the process descriptions. A qualitative description of potential pollution sources is attempted when quantitative data were not available in the consulted literature.

Integration of industries makes it difficult to assess waste streams from a particular plant. The waste stream compositions and loading ultimately depend on such things as the other processes within the plant and waste management practices. Waste streams may be combined or segregated and one waste treatment facility may serve a large number of operations at one site.

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6. Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

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INDUSTRY ANALYSIS

This chapter provides an overview of the plastics and resins industry through a summary of information from the open literature describing industrial practice. Because of the wide range and complexity of the industry, this treatment necessarily describes only the more important processes and products. This type of summary eliminates many of the complexities and variations in processing, resulting in a somewhat simplified picture of the industry.

The major emphasis is on industrial processing practices, and description of the often complex subject of polymer chemistry was beyond the scope of this treatment.

Blending procedures as a part of the industrial processing are de-emphasized, causing some apparent inconsistencies in the process descriptions. It is recognized that, especially in the case of the solid molding powder products of this industry, various additives may be blended with the product before it is packaged for sales or storage. When these practices were indicated in the literature sources, they are mentioned in the process descriptions; however, chemical processing is stressed. Appendix A contains lists of various types of additives used in formulating various plastic products.

Information used in this chapter was found in books, encyclopedias, trade journal articles, and EPA documents. It is thought that inconsistencies encountered in these sources result mainly from the wide variation in processing methods within the industry and from the lag of technical literature behind technological advances. Confusion also results from data presented without specification of the processing method used.

Data deficiencies encountered in the preparation of the Industry Description include a lack of capacity and/or production data by company or location. An attempt was made to retrieve this information using statistics published by SIC codes. A compilation for companies categorized in SIC code 2821 provided production data for about half of the plastics producers listed in the 1976 Directory of Chemical Producers. This is thought to be a result of categorization of fabricators and resin producers in separate SIC codes. The extensive integration of plastics producers and fabricators appears to create difficulties in differentiating between the two types of companies. As a result, information based on SIC categories such as that provided by the Bureau of Census and the International Trade Commission may be inadequate, but it is used for lack of better data.

Data are given in metric units as specified by the ASTM Metric Practice Guide. Preferred base units and rules for rounding numbers converted from one system of units to another are described therein. Gas volumes given in standard cubic feet are assumed to be 60°F volumes and are converted to cubic meters at 0°C.

Each operation is accompanied by a flow sheet indicating input materials, processes (numbered rectangles), and product and by-product streams (large circles). Solid, liquid, and gaseous waste streams are indicated by small squares, triangles, and circles, respectively, attached to the numbered process rectangles. Process descriptions follow the flow sheets on which they are presented.

MASS ADDITION POLYMERIZATION PROCESSES

A number of important resins (plastics) are manufactured by mass polymerization, a system in which the purified monomer is allowed to polymerize under controlled conditions of temperature and reaction rate. The Mass Addition Polymerization Operation is concerned only with those monomers which dissolve their polymers and excludes those from which the polymer precipitates.

Mass polymerization is the method most frequently used in the laboratory to study new monomers and their copolymers; no extra variables are introduced with the addition of other substances, and the problem of heat removal is trivial. However, industrial operations on a larger scale must contend with large heats of reaction which must be removed, as the resulting high temperatures would cause the polymer product to break down. The high viscosity of the polymer often makes heat transfer difficult. Another problem encountered is the autoacceleration or gd effect encountered is some polymer systems, especially in methyl methacrylate. This effect is seen as a marked deviation from first order kinetics with an attendant increase in reaction rate and molecular weight.

Resins produced by this operation include polystyrene, ABS (acrylonitrile-butadiene-styrene), SAN (styrene-acrylonitrile), PVC (poly[vinyl chloride]), methyl methacrylate, and allyl resins. Polystyrene and its copolymers are the primary resins commercially manufactured by a pure mass polymerization process. Methyl methacrylate and allyl resins (allyl casting resin syrups) are produced commercially by mass polymerization on a small scale for specialty items.

There are three processes involved in this operation. The polymer is formed from the monomer in the Polymerization Process (No. 1). The Vacuum Stripping Process (No. 2) removes the impurities from the product, and the Pelletizing and Bagging Process (No. 3) cuts and packages the polymer products. The sequence of processing is illustrated diagrammatically on Figure 3.

Utility requirements were largely unavailable in the literature consulted. Some requirements are listed for polystyrene production by the mass addition method. Since the basis is mass of product, the values include requirements for all three of the processes. For this reason the utility requirements are listed in Table 7.

A product-specific treatment of waste water from the plastics and resins industry defines waste water loading and raw waste loads for a few products made by this operation. They are presented here in Table 8, since they include waste from the entire plant.

Table 7. UTILITY REQUIREMENTS FOR POLYSTYRENE PRODUCTION BY MASS POLYMERIZATION[a]

Power	340 kWh
Steam (500 kPa)	400 kg
Process Water	2.5m^3

[a] Based on 900 kg production (1 ton)

Source: Polystyrene--Mitsui Toatsu Chem., Inc. Hydrocarbon Processing, 50:202, November 1971.

Table 8. WASTE WATER DATA FOR PRODUCTS MADE IN MASS ADDITION OPERATIONS

Product	Waste Water Loading (m^3/Mg Product)	Raw Waste Load (kg/Mg product)		
		BOD$_5$	COD	SS
Poly(vinyl chloride)	2.5-41.72	0.1-48	0.2-100	1-30
ABS/SAN	1.67-24.03	2-20.7	5-33.5	0-30
Polystyrene	0-141.8	0-2.2	0-6.0	0-8.4

Source: Environmental Protection Agency, Effluent Guidelines Division. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Polymers Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-75/036-b. Washington, D. C., Jan. 1975.

Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

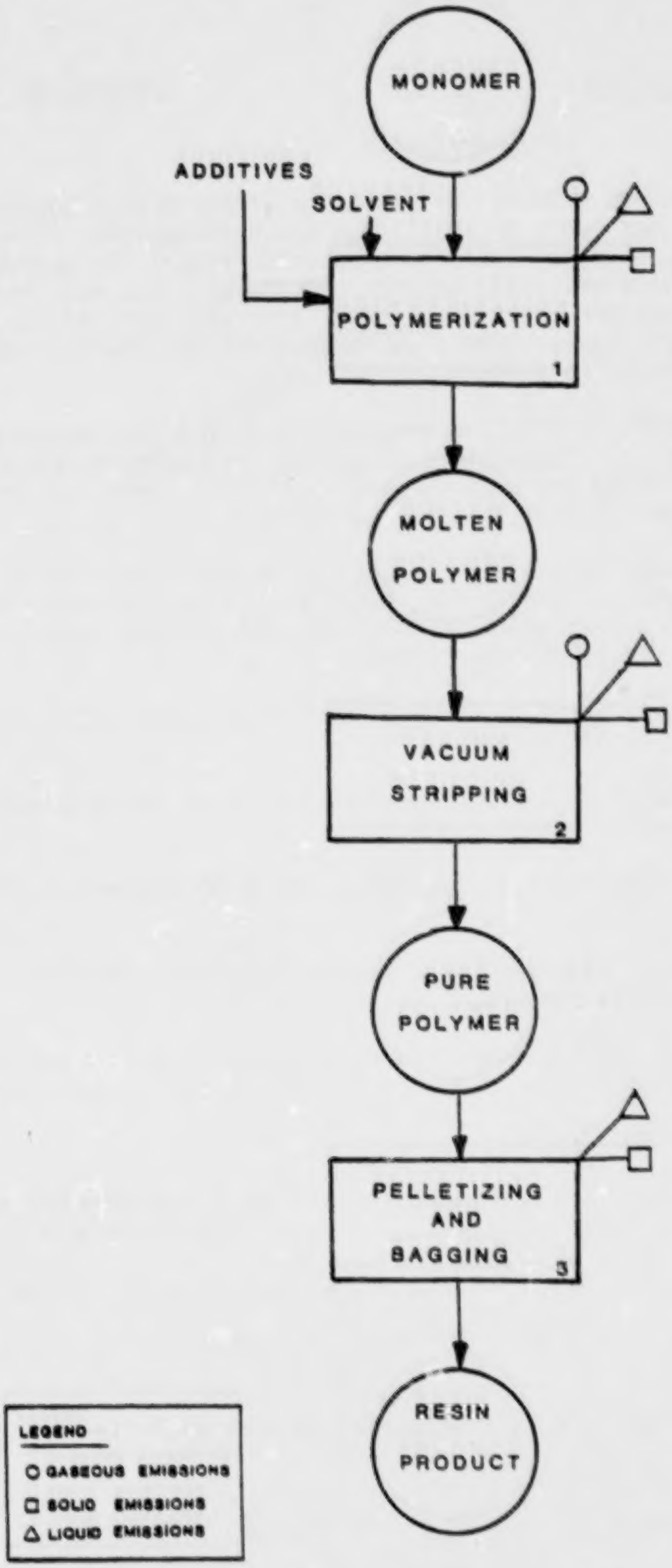
MONOMER
ADDITIVES
SOLVENT
POLYMERIZATION
1
MOLTEN
POLYMER
VACUUM
STRIPPING
2
PURE
POLYMER
PELLETIZING
AND
BAGGING
3
RESIN
PRODUCT
LEGEND
○ GASEOUS EMISSIONS
□ SOLID EMISSIONS
△ LIQUID EMISSIONS

FIGURE 3. MASS ADDITION POLYMERIZATION

Polymerization

1. Function - This process produces polymeric materials from a purified monomer material in a continuous or multistage batch operation. After removal by distillation or washing of inhibitors used to protect the monomers from autopolymerization in storage, small amounts of catalysts and modifiers are added which will initiate the reaction, control its rate, and influence the molecular weight of the polymer. These substances are not easily recoverable and the residues remain in the product.

The monomer is brought to reaction temperature by indirect heating in a stirred, jacketed kettle. Temperature control is accomplished through circulating heat transfer fluid and heat exchange equipment. When the reaction is completed, the polymer is sent to a vacuum stripper.

2. Input Materials - Input materials include the monomer required for the specific product: styrene, acrylonitrile, butadiene, vinyl chloride, methylacrylate, or allyl esters of aromatic acids. For polystyrene about 1.1 kg of styrene is required per kg of polystyrene.

For polystyrene approximately 0.03 kg of additives (catalysts and modifiers) are required per kg of product.

About 0.004 kg of inert solvents (viscosity reducers) are required to produce 1 kg of polystyrene.

It is thought that conversion is limited to 50 to 60 percent in PVC production.

3. Operating Parameters - Equipment used includes stirred, jacketed resin reaction kettles and heat exchangers.

Conditions are different for each polymer product. The temperature for making polystyrene is initially 90°C and is raised to 150° or possibly 200°C.

4. Utilities - See Table 7.

5. Waste Streams - Possible liquid waste streams are inhibitor-wash waste, oil leaks in the heat exchange equipment, and water from washdown of spills.

Excess or substandard product is produced as a solid waste stream.

Fugitive gaseous emissions of volatile monomer material may also be produced.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Bishop, Richard B. Find Polystyrene Plant Costs. Hydrocarbon Processing, 51:137-140, November 1972.

(2) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

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Vacuum Stripping

1. Function - The molten polymer from the reaction kettle is pumped by means of vented twin screw extruders to a vacuum stripper (devolatilizer) to remove unreacted monomer and small amounts of contaminants and by-products. Vapors from the vacuum stripper pass through an oil-cooled tar condenser. The condenser vent is connected to a steam jet ejector; steam and volatile hydrocarbons condense in a water-cooled surface condenser. Phase separation is accomplished by decanting. The oils are recovered, and contaminated condensate goes to the process sewer. Tars and oligomer form a solid waste stream. The isolated molten polymer is extruded from the bottom of the stripper.

2. Input Materials - Molten polymer from the reactor is the input material.

3. Operating Parameters - The vacuum stripper operates at 3.1 kPa (29 in Hg)

4. Utilities - See Table 7.

5. Waste Streams - Possible sources of liquid waste are contaminated condensate and condenser leaks.

Fugitive gaseous emmissions are possible from the stripper (valves, condensers, vents, seals, etc.). Emissions may also result in the form of light ends from the decanter.

Solid waste in the form of tars and oligomers also results from the phase separation.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02.

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(1) Bishop, Richard B. Find Polystyrene Plant Costs. Hydrocarbon Processing, 51:137-140, November 1972.

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(4) Polystyrene--Ato Chimie. Hydrocarbon Processing, 54:198, November 1975.

(5) Polystyrene--Mitsui Toatsu Chem., Inc. Hydrocarbon Processing, 50:202, November 1971.

Pelletizing and Bagging

1. Function - Ribbons of pure molten polymer are extruded from the bottom of the stripper through a water bath. The polymer strands are then cut into granules or pellets and the finished product is packaged.

2. Input Materials - Purified polymer from the stripper and cooling water are input materials to this process.

3. Operating Parameters - The extrusion temperature range is 150° to 180°C for poly(vinyl chloride) and 190° to 260°C for polystyrene. Table 9 presents production capacities for various sizes of screw extruders processing poly (vinyl chloride).

Table 9. PRODUCTION CAPACITIES OF SCREW EXTRUDERS FOR 0.64 cm (0.25 in) ROD[a]

Diameter of Screw		Productive Capacity	
cm	in	kg/hr	lb/hr
5	2	10-20	30-50
6.4	2.5	20-30	40-75
8.3	3.25	34-57	75-125
8.9	3.5	43-68	95-150
11.4	4.5	68-90	150-200
15	6.0	110-140	250-350

[a] polyvinyl chloride, sp. gr. 1.35

4. Utilities - See Table 7.

5. Waste Streams - An aqueous waste stream containing polymer fines may result from pelleting procedures.

Solid waste in the form of particulates, fines, and chunks may result from pelleting and bagging. Particulates may also be emitted if pneumatic conveying systems are employed.

6. EPA Source Classification Code - Polyprod. General 3-018-01-02

7. References -

(1) Bishop, Richard B. Find Polystyrene Plant Costs. Hydrocarbon Processing, 51:137-140, November 1972.

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(4) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N. Y., Van Nostrand Reinhold, 1974, p. 258-59.

(5) Polystyrene--Ato Chimie. Hydrocarbon Processing, 54:198, November 1975.

(6) Polystyrene--Mitsui Toatsu Chem., Inc. Hydrocarbon Processing, 50:202, November 1971.

EMULSION ADDITION POLYMERIZATION PROCESSES

Emulsion polymerization is a two-phase polymerization system. It is characterized and differentiated from suspension polymerization by the location of the initiator in the aqueous phase and by the size of the particles produced (10nm-1μm).

The polymer product is usually marketed in the latex form (for paints, adhesives, paper coatings, etc.) but may be sold as a dry resin. Latex materials produced in this operation include polystyrene, ABS (acrylonitrile-butadiene-styrene), SAN (styrene-acrylonitrile), PVC (poly[vinyl chloride]), PVA (poly[vinyl acetate]), poly(vinylidene chloride), poly(alkyl acrylates) and and copolymers, poly(alkyl methacrylates) and copolymers, poly(vinyl esters) and copolymers, polyacrylonitrile, polybutadiene, polychloroprene, polyisoprene, α-methylstyrene copolymers, and isobutylene copolymers.

Some of the solid products of this operation include poly(vinyl chloride) plastisol resins, styrene-acrylonitrile graft polyblends with synthetic rubbers, teflon (polytetrafluoroethylene), and Kel-F (polytrifluorochloroethylene).

Advantages offered by emulsion polymerization are the ability to form a high molecular weight product at a high reaction rate, the ease of heat transfer, and the lower viscosity of the emulsion compared to a polymer solution. This type of polymerization produces very finely divided particles which can be of very uniform size distribution. A disadvantage for some applications is the contamination of the product with emulsifiers and other chemical additives.

A product specific treatment of plastics and resins manufacture presented some waste water data for several products made by this operation. Because the data include waste water from the entire operation, they are included here in Table 10.

Table 10. WASTE-WATER DATA FROM EMULSION POLYMERIZATION

Product	Waste-Water Loading (m^3/Mg product)	Raw Waste Load (kg/Mg product)		
		BOD_5	COD	SS
Poly(vinyl chloride)	2.5-41.72	0.1-48	0.2-100	1-30
ABS/SAN	1.67-24.03	2-20.7	5-33.5	0-30
Poly(vinyl acetate)	0-25.03	0-2	0-3	0-2
Fluorocarbon polymers	18.4-152.7	0-6.6[a]	4.4-44[a]	2.2-6.6[a]
Poly(vinylidene chloride)	4.2[a]	0[a]	8[a]	0.2[a]

[a] Estimated

Source: See next page

Source: Environmental Protection Agency, Effluent Guidelines Division. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Polymers Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-75/036-b. Washington, D. C., Jan. 1975.

Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

Two processes are described: 4) Polymerization which results in a latex product and 5) Dry Product Preparation, producing a dry resin through coagulation and drying methods. Figure 4 is a process flow chart included as an aid in understanding the processing methods.

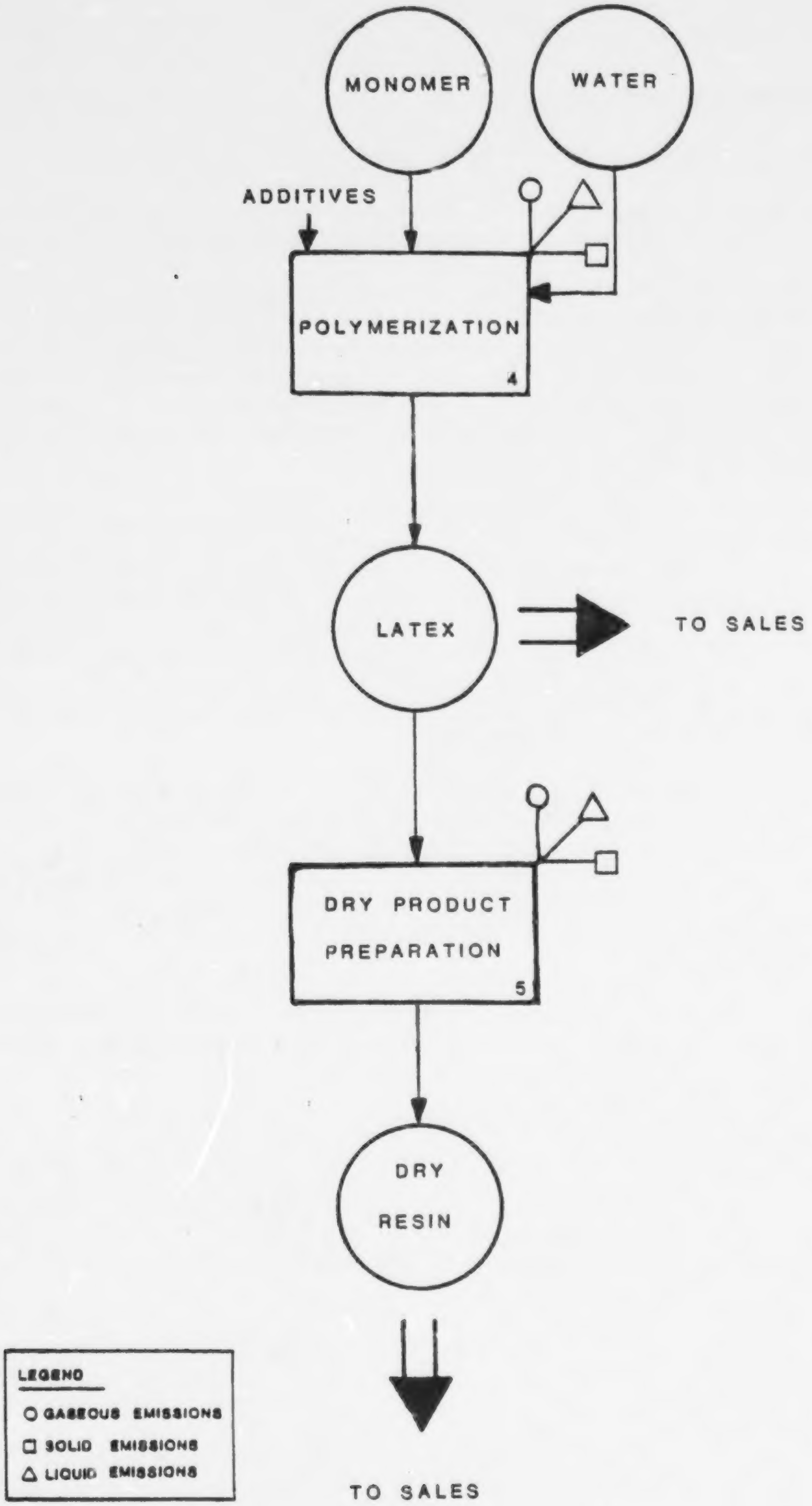
MONOMER
WATER
ADDITIVES
POLYMERIZATION
4
LATEX
TO SALES
DRY PRODUCT PREPARATION
5
DRY RESIN
TO SALES
LEGEND
○ GASEOUS EMISSIONS
□ SOLID EMISSIONS
△ LIQUID EMISSIONS

FIGURE 4. EMULSION ADDITION POLYMERIZATION

Polymerization

1. Function - In this process a latex polymer product is produced from an emulsion feedstock of monomer in a continuous liquid phase, usually water.

After removal of inhibitors from the monomer material by washing, an emulsion is made by addition of monomer and emulsifier to deionized or distilled water. The reaction is initiated by formation of micelles, aggregates of emulsifier molecules. The critical micelle concentration (cmc) is the concentration below which micelles will not form and is characteristic of a specific emulsifier. The emulsifying agent must be added in concentrations exceeding the cmc.

If a batch cycle is used, the emulsion of monomer is introduced into a stirred, jacketed reactor containing an emulsified solution of various chemical additives such as catalysts, initiators, and chain transfer agents. Reactors may be equipped with reflux condensers if the polymer does not have heavy fouling tendencies. Turbine agitators are often employed, but large-diameter, slow-speed impellers are used in some emulsion systems which are sensitive to coagulation due to shearing. Double mechanical seals are commonly used in the agitator, and lubricants are chosen carefully, as some leakage into the reactor always results.

The reactor temperature is controlled by circulating water or steam through the jacket. Additional methods of heat removal are continuous addition of cold monomer, reflux condensing, and side-stream cooling through heat exchange. It is not possible to use refluxing and heat exchange with all polymers because of temperature sensitivity and fouling tendencies. However, if a reflux condenser is used, volatilized monomer and water are recirculated to the reactor.

When the reaction is completed, the polymer is drawn off through a screen to remove oversize particles which are landfilled. The remaining monomer is then removed by flashing, usually in a vertical tank, and steam stripping in single or multiple stages.

Continuous operations may utilize tubular reactors, a series of agitated reactors, or towers.

2. Input Materials - Input materials include monomers, initiators, emulsifiers, chain transfer agents, redox catalysts, and stabilizers. Examples are given below.

Monomers - include styrene, acrylonitrile, butadiene, vinyl chloride, vinylidene chloride, tetrafluoroethylene, trifluorochloroethylene, vinyl acetate, alkyl acrylates, alkyl methacrylates, chloroprene, isoprene, α-methylstyrene, and isobutylene.

Initiators - usually water soluble peroxidic compounds such as hydrogen peroxide, urea peroxide, potassium persulfate, sodium perborate, ammonium peroxysulfate, and cumene hydroperoxide.

Emulsifiers - include soaps of long-chain alcohols, salts of aliphatic and aromatic sulfonic acids, aliphatic amines and their salts.

Modifier or chain transfer agent - mercaptans, halogenated aliphatic hydrocarbons, or hydrocarbons with an active hydrogen such as cumene.

Redox catalyst - water soluble, inorganic reducing agent, commonly chelated iron.

Stabilizers and buffering agents may be added to protect the emulsion from breaking. These include casein, glue, albumin, starch, methyl cellulose, poly (vinyl alcohol), phosphates, carbonates, and other additives.

Also added are small amounts of oxygen scavengers such as sodium dithionite.

Table 11 illustrates typical emulsion polymerization "recipes." The lower limit of emulsifer concentration is indicated by the cmc values in Table 12 for various emulsifiers.

Table 11. INPUT MATERIALS FOR PRODUCTION OF POLYSTYRENE AND POLY (VINYL CHLORIDE) BY EMULSION POLYMERIZATION METHODS.

Polymer	Chemical	Parts by Weight
polystyrene	sytrene	100
	sodium oleate	6
	potassium persulfate	0.3
	water	150
poly (vinyl chloride)	vinyl chloride	40-50
	fatty sulphonate	0.4-0.6
	fatty alcohol	0.4-0.6
	lauroyl peroxide	0.4-0.5
	water	100

Table 12. CMC VALUES FOR TYPICAL EMULSIFIERS[a]

Emulsifier	Cmc (moles/ℓ)
potassium caprylate	0.393
potassium caprate	0.105
potassium laurate	0.026
potassium myristate	0.0059-0.0072
potassium palmitate	0.003
potassium stearate	0.0008
potassium oleate	0.001
sodium decyl sulfonate	0.04
sodium dodecyl sulfonate	0.0098
sodium tetradecyl sulfonate	0.0027
sodium decyl sulfate[b]	0.023
sodium dodecyl sulfate[b]	0.0057
potassium dehydroabietate	0.025-0.03
sodium rosenate	<0.01

[a] 50°, in pure water
[b] temperature not specified

3. Operating Parameters- The polystyrene polymerization reaction presented in Table 11 takes place at 70°C. One source of information indicates typical reaction times of 18 to 30 hours at temperatures of 45° to 75°C. With the use of redox catalysts the reaction may proceed at very low temperatures (0°C) and may require much shorter reaction times.

The pressure in the reactor may begin at 0.5-1.5 MPa (5-15 atm) for PVC polymerization; it decreases as the reaction proceeds. Reaction times may be as short as six hours.

Typical reactor volumes are from 20 to 100 m^3 (5000 to 30,000 gal). Reactors are usually glass-lined or stainless steel.

Table 13 indicates effective pH ranges for various types of emulsifiers.

Overall heat transfer coefficients of emulsion systems are usually 340 $W/m^2{}^\circ C$ (40-60 $Btu/hrft^2{}^\circ F$) for turbine agitated reactors. Agitation heat input is about 5 percent of the total for emulsion polymerization systems. Shear sensitive latices may require pump type agitation.

Table 13. EFFECTIVE pH RANGE OF EMULSIFIERS

Emulsifier	pH Range
C_{12}-C_{18} soaps	9-11
ammonium or amino soaps	8-9
alkyl sulfates and alkyl sulfonates	wide pH range
salts of amines, quartenary ammonium salts of long-chain substituted cyclic amines	acid pH
Non ionic emulsifiers, such as polyalcohols and esters	insensitive to pH

4. Utilities - Agitation requires 0.6-2W/m^3 (3-10hp/1000 gal).

5. Waste Streams - Fugitive gaseous emissions of volatile monomer may occur at leaks in equipment, vents, valves, and rupture discs.

A solid waste stream results from the oversize latex screenings; these are landfilled.

Water used to wash the inhibitors from the monomers prior to reaction forms a wastewater stream. Additional liquid waste may result from leaks in processing equipment.

Cleaning of reactors is accomplished by mechanical removal of solid deposits or by washing down the sides of the reactor with solvent or high-pressure steam. The literature contained no information concerning the disposition of this waste stream.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

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(3) Duck, Edward W. Emulsion Polymerization. In: Encyclopedia of Polymer Science and Technology, Vol. 6. H.F. Mark, ed. N.Y., Wiley, 1966, p. 801-59.

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(5) Hahn, A. V. The Petrochemical Industry - Market and Economics. N.Y., McGraw-Hill, 1970, p 299-300.

(6) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 260.

(7) Lenz, Robert. Polymerization, Mechanisms and Processes. In: Kirk-Othmer Encyclopedia of Chemical Technology, Vol 16. Anthony Standen, ed. N.Y., Wiley, 1968, p. 219-42.

(8) Matthews, George. Vinyl and Allied Polymers. Vol 2. Vinyl Chloride and Vinyl Acetate Polymers. London, Iliffe Books, 1972.

(9) Oringer, Kenneth. Current Practice in Polymer-Recovery Operations. Chemical Engineering, 79:29-106, 20 March 1972.

(10) Pervier, J. W., et al. Survey Reports on Atmospheric Emissions from the Petrochemical Industry, 4 Vols. EPA 450/3-73-005 a-d, Contract No. 68-02-0255. Air Products & Chemicals, Houndry Div., March 1974.

(11) Schlegel, Walter F., Design and Scaleup of Polymerization Reactors. Chemical Engineering, 79:88-95, 20 March 1972.

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EMULSION ADDITION POLYMERIZATION — PROCESS NO. 5

Dry Product Preparation

1. Function - In this process a dry resin product is formed from the latex material resulting from emulsion polymerization. Coagulation is accomplished by the addition of a chemical substance to break the emulsion, by freezing, by agitation, by ultrasonic vibration, or by forcing the latex through jets (shearing).

The coagulated polymer which contains 40 to 65 percent water must then be dried. Product specifications are usually 0.1 to 1.0% water (wet basis). Drying may be accomplished by milling on heated rollers or in spray, rotary, or flash driers.

Spraying the latex into a heated gas chamber is an often used method which accomplishes coagulation and drying in one step. The polymer is then compressed into pellets for sale as a finished dry product.

2. Input Materials - Latex formed by emulsion polymerization and chemical additives to break the emulsion (acids, electrolytes, flocculating agents) are input materials to this process.

3. Operating Parameters - None were available in the sources consulted for this study.

4. Utilities - None were available in the sources consulted for this study.

5. Waste Streams - Gaseous emissions of monomer or other low boiling compounds may result in the drying section of the plant. Waste water also results from the dryers, and it may be contaminated with various chemicals: monomer, initiators, modifiers, emulsion breakers, etc. Dusting in the driers has the potential for producing particulate emissions if the dust collecting methods are inadequate.

5. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Basel, L. and J. Papp. Polymerization Procedures, Industrial. In: Encyclopedia of Polymer Science & Technology. Vol 11. H. F. Mark, ed. N.Y., Wiley, 1969, p. 280-304.

(2) Billmeyer, Fred W., Jr. Textbook of Polymer Science, 2nd Ed. N.Y., Wiley, 1971.

(3) Duck, Edward W. Emulsion Polymerization. In: Encyclopedia of Polymer Science and Technology, Vol. 6. H. F. Mark, ed. N.Y., Wiley, 1966, p. 801-59.

(4) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(5) Hahn, A. V. The Petrochemical Industry - Market and Economics. N.Y., McGraw-Hill, 1970, p. 299-300.

(6) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 260.

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(8) Matthews, George. Vinyl and Allied Polymers, Vol 2. Vinyl Chloride and Vinyl Acetate Polymers. London, Iliffe Books, 1972.

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SUSPENSION ADDITION POLYMERIZATION PROCESSES

Suspension polymerization is similar to emulsion polymerization in that the monomer is dispersed rather than dissolved in the continuous phase. It differs from emulsion polymerization in the location of the initiator in the monomer phase and in the size of the polymer particles produced (50-2000μ). Although reaction times required are longer than in an emulsion polymerization, the product is obtained in the form of spherical beads rather than in the latex form. This fact makes possible the recovery of a polymer product of higher purity than in the emulsion process in which coagulation of latex results in inclusion of chemical additives. The suspension polymerization product is easily washed and dried to form the final dry product. Other advantages of this process include good heat transfer and low viscosity due to the suspension of particles in the continuous phase.

Polymers produced by a commercial suspension process include poly (methacrylic esters) and copolymers, polyacrylic esters and copolymers, polystyrene, rubber-modified polystyrene, poly(vinylidene chloride)-vinyl chloride copolymers, poly(vinyl chloride) (PVC) and copolymers, PVA (poly [vinyl acetate]), SAN (styrene-acrylonitrile copolymers), rubber-modified styrene-acrylonitrile copolymers, i.e., ABS and others, poly(divinylbenzene) and copolymers, and poly(chlorotrifluoroethylene) and copolymers. Of these polymers poly (vinyl chloride) is produced in the largest quantities; this is the major method for PVC production.

Figure 5 shows that there are three processes presented in this operation: 6) Polymerization, 7) Polymer Isolation, and 8) Final Product Preparation. These processes accomplish the transformation of a monomer into a dry polymer product.

A product-specific treatment of this industry presents waste-water data for several products made by this operation. The data are included in Table 14, as they pertain to the whole operation.

Table 14. WASTE-WATER DATA FOR SUSPENSION POLYMERIZATION PRODUCTS

Product	Waste-water Loading (m^3/Mg) product	Raw Waste Loads (kg/Mg product) BOD_5	COD	SS
Poly (vinyl chloride)	2.5-41.72	0.1-48	0.2-100	1-30
ABS/SAN	1.67-24.03	2-20.7	5-33.5	0-30
Poly (vinylidene chloride)	4.2[a]	0[a]	8[a]	0.2[a]
Polystyrene	0-141.8	0-2.2	0-6.0	0-8.4
Poly (vinyl acetate)	0-25.03	0-2	0-3	0-2

[a] Estimated

Source: Environmental Protection Agency, Effluent Guidelines Division. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Polymers Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-75/036-b. Washington, D. C., Jan. 1975.

Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

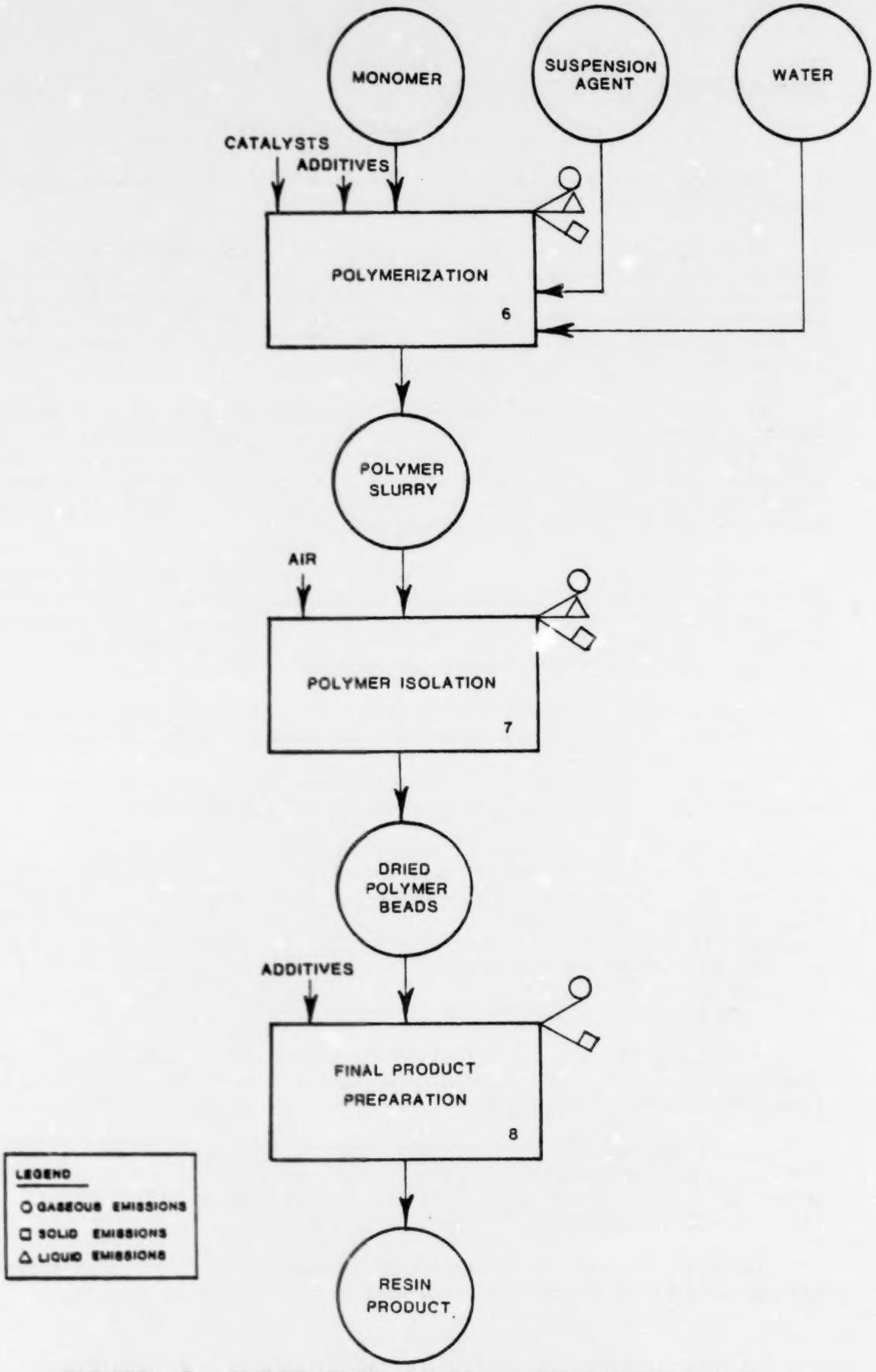

MONOMER
SUSPENSION AGENT
WATER
CATALYSTS
ADDITIVES
POLYMERIZATION
6
POLYMER SLURRY
AIR
POLYMER ISOLATION
7
DRIED POLYMER BEADS
ADDITIVES
FINAL PRODUCT PREPARATION
8
RESIN PRODUCT
LEGEND
○ GASEOUS EMISSIONS
□ SOLID EMISSIONS
△ LIQUID EMISSIONS

FIGURE 5. SUSPENSION ADDITION POLYMERIZATION

Polymerization

1. Function - Liquid monomer is transformed into solid globules of polymer product in this process.

In a typical batch process the atmosphere in the reaction kettle is purged with an inert gas prior to charging a suspension agent along with distilled or deionized water. The monomer may be prepared by washing with water to remove protective inhibitors. Initiator is added to the monomer, and the resulting solution is added to the reactor. Continuous agitation and temperature control are applied until the reaction is completed.

Agitation is of utmost importance in this process as it is a controlling factor in particle sizing. Turbine, anchor, and paddle agitators have been used; baffles have also been used as an aid to agitation. To ensure thorough agitation, the agitator equipped with double mechanical seals is commonly located near the bottom. Lubricants must be chosen very carefully, as a small amount of leakage at the seals always results.

Temperature control is achieved primarily through the use of steam/water jackets on the reactors. A few polymers may be cooled with reflux cooling and by circulation through a heat exchanger, but fouling and temperature sensitivities prohibit this practice for many polymers. If reflux cooling is utilized, the vaporized monomer and water vapor are returned to the reactor.

Residual monomer is flashed in single or multiple stages, usually in vertical flash tanks. This procedure is usually followed by steam or vacuum stripping.

Commercial processes are generally of the batch cycle type, but a series of reactors is sometimes employed in continuous processing methods.

2. Input Materials - Monomers may include the following: methacrylic acid esters, acrylic acid esters, styrene, vinylidene chloride, vinyl chloride, vinyl acetate, acrylonitrile, butadiene, divinylbenzene, tetrafluoroethylene, and chlorotrifluoroethylene. Suspension agents such as (tri)calcium phosphate (hydroxy apatite), barium sulfate, aluminum hydroxide, bentonite clay, calcium oxalate, gelatin, poly(vinyl pyrrolidone), poly(vinyl alcohol), carboxymethylcellulose, hydroxyethylcellulose, polyacrylic acid, polymethacrylic acid, acrylic-methacrylic acid, and ester copolymers have been used.

Initiators are monomer-soluble catalysts, in many cases organic peroxides. Some initiators which have been used are benzoyl peroxide, diacylperoxides, lauroyl peroxide, diisopropylperoxy dicarbonate, and t-butylperoxypivalate.

Stabilizers which have been used include poly(vinyl alcohol), tragacanth gum, salts of styrene-maleic anhydride copolymers, vinyl acetate-maleic anhydride copolymers and salts, starch, gelatin, and methylcellulose. Purified (distilled or deionized) water is also required.

The ratio of water to monomer varies from 1:1 to 4:1. Input materials to typical suspension polymerization processes are listed in Table 15.

Table 15. INPUT MATERIALS TO TYPICAL SUSPENSION POLYMERIZATION PROCESSES

Component	Parts per 100 Parts of Monomer		
	Styrene	Methyl Methacrylate	Vinyl Chloride
Water	200	350	150 - 350
Peroxide initiator	0.1	0.5	0.1 - 0.5
Stabilizers	0.1	0.01 - 1	0.01 - 1

3. Operating Parameters - Poly(vinyl acetate) is processed in a reactor capable of withstanding 300 kPa (50 psi). The reaction temperature is about 70°C. Agitators used are generally of the anchor or paddle type. Reflux cooling is frequently employed.

Poly(vinyl chloride) reactors are rated at a minimum of 1 MPa (200 psi). This pressure exceeds the vapor pressure of vinyl chloride at the reaction temperature by 300 kPa (50 psi). Relief valves generally have an orifice area of 0.00020 m^2/m^3 (0.0012 in^2/gal) of reactor capacity. Reaction temperature is 50°C (122°F). The required coolant temperature at the maximum conversion rate for a 14 m^3 (3700 gallon) reactor is 5°C (41°F), necessitating the use of refrigerated water. Total reaction time is 12 hours per batch. The same reactor has an overall heat transfer coefficient of 312 W/m^2K (55 Btu/hr ft^2 °F).

One source indicates that for polymerization of styrene in a 19 m^3 (5000 gal) reactor equipped with internal cooling baffles, the lowest coolant temperature required is 49°C (120°F). This allows the use of cooling tower water to control the temperature. Another source of information specifies temperature and reaction times for polystyrene: 6 hours at 90°C, then 8 hours at 130°C.

The size of the polymer beads is determined by agitation rates and efficiencies, amounts of stabilizers and catalysts, temperature, and pH. Usual temperatures range from 40°C to 90°C. Typical reactor volumes are 20 to 100 m^3 (5000 to 30,000 gal). Reactors are usually glass-lined steel or stainless steel. Heat input from agitation is usually 5 percent or less of the total heat input.

4. Utilities - Agitation power input is commonly 1 kW/m (6 to 7 hp/1000 gal).

5. Waste Streams - A liquid waste stream results from water-washing to remove inhibitors from monomer feedstocks.

Fugitive gaseous emissions of volatile monomer materials may occur at vents, valves, flanges, seals and at leaks in equipment. In the production of PVC 0.0009 kg of vinyl chloride are emitted in this way per kg of PVC produced.

Cleaning of reactors is accomplished by mechanical methods or by washing with solvent or high-pressure steam. Although no information was found concerning the disposition of this material, a solid and/or liquid waste steam is assumed.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Basel, L. and J. Papp. Polymerization Procedures, Industrial, In: Encyclopedia of Polymer Science & Technology, Vol 11. H. F. Mark, ed. N.Y., Wiley, 1969, p. 280-304.

(2) Billmeyer, Fred W., Jr. Textbook of Polymer Science, 2nd Ed. N.Y., Wiley, 1971.

(3) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(4) Farber, Elliott. Suspension Polymerization. In: Encyclopedia of Polymer Science and Technology, Vol 18. H. F. Mark. ed. N.Y., Wiley, 1970, p. 552-71.

(5) Hahn, A. V. The Petrochemical Industry - Market and Economics. N.Y., McGraw-Hill, 1970, p. 299.

(6) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 263.

(7) Lenz, Robert. Polymerization Mechanisms and Processes. In: Kirk-Othmer Encyclopedia of Chemical Technology, Vol. 16. Anthony Standen, ed. N.Y., Wiley, 1968, p. 219-42.

(8) Matthews, George. Vinyl and Allied Polymers. Vol 2. Vinyl Chloride and Vinyl Acetate Polymers. London, Iliffe Books, 1972.

(9) Pervier, J. W., et al. Survey Reports on Atmospheric Emissions from the Petrochemical Industry, 4 Vols. EPA 450/3-73-005 a-d, Contract No. 68-02-0255. Air Products & Chemicals, Houdry Div., March 1974.

(10) Polystyrene--Cosden Technology, Inc. Hydrocarbon Processing, 54:199, November 1975.

(11) Polyvinylchloride--Ato Chimie. Hydrocarbon Processing, 54:200, November 1975.

(12) Schlegel, Walter F. Design and Scaleup of Polymerization Reactors. Chemical Engineering, 79:88-95, 20 March 1972.

(13) Unit Processes in Organic Synthesis, 5th Ed. Philip H. Groggins, ed. N.Y., McGraw-Hill, 1958, p. 943-1035.

Polymer Isolation

1. Function - The solid and liquid phases of the polymer slurry are separated in this process by centrifugation and/or filtration. Large-scale processes commonly use drum-type belt filters, horizontal belt filters, perforate basket centrifuges, solid-bowl centrifuges, and pusher centrifuges to remove about 90 percent of the water. Rotary driers are most often used to provide a moisture content of 0.1 to 1 percent (wet basis). Other types of driers may also be used. Fluid-bed driers find an application in this process for drying polystyrene beads.

2. Input Materials - A slurry of polymer beads is the input to this process. Direct drying with air requires 0.2 to 0.3 m^3/min (8 to 10 ft^3/min) of air to remove 0.5 kg (1 lb) of water.

3. Operating Parameters - Rotary driers usually operate at 5 to 15 percent of their total volume. Air velocities usually range from 2 to 20 Mg/hr m^2(400 to 4000 lb/hr ft^2). The peripheral speed of operation is 9 to 30 m/min (30 to 100 ft/min). The slope of the shell varies from 0 to .08 cm/m (0 to 1 in./ft). Typical residence times are 5 to 20 min. The cylinder length may be 4 to 10 times its diameter; 4 meter (12 foot) diameters are typical of large polymer operations.

Piping for transport of the beads within the plant is of stainless steel to prevent contamination of the product.

4. Utilities - Estimated power requirements for centrifuges handling concentrated slurries are summarized in Table 16.

Table 16. CENTRIFUGE POWER REQUIREMENTS

Centrifuge type	Power required (kWh/kg)	Power required (kWh/ton)
helical conveyor centrifuge up to 61 cm (24 in.)	0.013 - 0.017	12 - 15
helical conveyor centrifuge larger than 61 cm (24 in.)	0.002 - 0.01	2 - 10
automatic batch centrifugal	0.004 - 0.007	4 - 6
reciprocating conveyor centrifugal	0.002 - 0.004	2 - 4
oscillating-screen centrifugal	0.0002- 0.0003	0.2 - 0.3
batch centrifugal	0.006 - 0.03	5 - 25

The total horsepower required for rotary driers (including fans, drier drive, and conveyors) is estimated at (0.5 to 1) D^2 where D is the diameter in feet.

Power requirements for fluid-bed dryers are about 0.081 kWh/kg (0.037 kWh/lb) of water removed.

5. Waste Streams - Gaseous emissions of water vapor and low boiling compounds may result from the dryer. Fugitive emissions from this part of the plant amount to 0.0112 kg of hydrocarbon per kg of polymer produced in PVC plants.

Liquid waste streams containing water, monomer, and chemical additives result from centrifugation, filtration and drying operations.

Rotary driers have the potential for causing dusting. Dust collectors are necessary to recover the product. A plant utilizing cyclones for dust collectors will suffer product losses of 1 percent of its capacity. Assuming an annual capacity of 23 Gg (50 million lb), a loss of 230 Mg (500,000 lb) would result. It is clearly evident that this method of dust collection is not adequate. An average of particulate emissions from PVC plants based on EPA questionnaires is 0.0020 kg of particulates per kg of PVC produced.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Billmeyer, Fred W., Jr. Textbook of Polymer Science, 2nd Ed. N.Y., Wiley, 1971.

(2) Chemical Engineers' Handbook, 4th Ed. Robert H. Perry, ed. N.Y., McGraw-Hill, 1963.

(3) Environmental Protection Agency, (office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(4) Farber, Elliott. Suspension Polymerization. In: Encyclopedia of Polymer Science and Technology, Vol 18. H. F. Mark, ed. N.Y., Wiley, 1970, p. 552-71.

(5) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 263.

(6) Matthews, George. Vinyl and Allied Polymers. Vol 2. Vinyl Chloride and Vinyl Acetate Polymers. London, Iliffe Books, 1972.

(7) Oringer, Kenneth. Current Practice in Polyer-Recovery Operations Chemical Engineering, 79:29-106, 20 March 1972

(8) Pervier, J. W., et al. Survey Reports on Atmospheric Emissions from the Petrochemical Industry, 4 Vols. EPA 450/3-73-005 a-d, Contract No. 68-02-0255. Air Products & Chemicals, Houdry Div., March 1974

(9) Polystyrene--Cosden Technology, Inc. Hydrocarbon Processing, 54:199, November 1975.

(10) Polyvinylchloride--Ato Chimie. Hydrocarbon Processing, 54:200, November 1975.

(11) Unit Processes in Organic Synthesis, 5th Ed. Philip H. Groggins, ed. N.Y., McGraw-Hill, 1958, p. 943-1035.

Final Product Preparation

1. Function - The dried polymer beads from Process No. 7 are mixed with various chemical additives such as colorants, plasticizers, and stabilizers. The mixture is melted and thoroughly mixed in a Banbury mixer or in an extruder. The plastic material then enters an extruder, usually of the screw type. Devolatilization is accomplished by passing the hot polymer through an evacuated zone of the extruder to reduce the concentration of volatiles to 0.5 percent or lower. The extruded plastic is cooled and pelletized, commonly with a multiknife pelletizer. The product is then bagged or packaged for sales.

2. Input Materials - Polymer beads and additives to alter the characteristics of the polymer product are input materials to this process.

3. Operating Parameters - Pressure inside Banbury mixers is commonly 0.10 to 0.14 MPa (15-20 psi).

Extrusion temperature ranges are 150 to 180°C (300 to 350°F) for poly (vinyl chloride), 190 to 260°C (375-500°F) for polystyrene, and 150-180°C (300-350°F) for vinylidene chloride resins.

Table 9 in Process No. 3 presents production capacities for various sizes of screw extruders processing poly(vinyl chloride).

4. Utilities - A No. 11 Banbury mixer operating at 20 rpm and processing 0.25 m^3/10 min (9 ft^3/10 min) consumes 190 kW (250 hp). If the same mixer operates at 40 rpm to process 0.25 m^3/5 min (9 ft^3/5 min) the power required is 370 kW (500 hp).

5. Waste Streams - Particulates may be emitted form the pelletizing and bagging steps. This source also has the potential for creating a solid waste stream resulting from spills in materials handling. If pneumatic conveyor systems are utilized, additional particulate emissions may occur. Particulates emitted from this section of a PVC plant amount to 0.0007 kg per kg of PVC product.

The devolatilization procedure has the potential for gaseous emissions of toxic monomer materials. Extrusion of polymer materials is often accompanied by cooling through direct contact with water. This type of quenching produces a waste-water stream containing polymer fines.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Chemical Engineers' Handbook, 4th Ed. Robert H. Perry, ed. N.Y., McGraw-Hill, 1963.

(2) Farber, Elliott. Suspension Polymerization. In: Encyclopedia of Polymer Science and Technology, Vol 18. H. F. Mark, ed. N.Y., Wiley, 1970, p. 552-71.

(3) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 263.

(4) Latinen, G. A. Devolatilization of Viscous Polymer Systems. Polymerization and Polycondensation Processes. In: Advances in Chemistry Series No. 34. Robert F. Gould, ed. Washington, D. C., ACS, 1962.

(5) Matthews, George. Vinyl and Allied Polymers. Vol 2. Vinyl Chloride and Vinyl Acetate Polymers. London, Iliffe Books, 1972.

(6) Oringer, Kenneth. Current Practice in Polymer-Recovery Operations. Chemical Engineering, 79:29-106, 20 March 1972.

(7) Pervier, J. W., et al. Survey Reports on Atmospheric Emissions from the Petrochemical Industry, 4 Vols. EPA 450/3-73-005 a-d, Contract No. 68-02-0255. Air Products & Chemicals, Houdry Div., March 1974.

(8) Polystyrene--Cosden Technology, Inc. Hydrocarbon Processing, 54:199, November 1975.

(9) Polyvinylchloride--Ato Chimie. Hydrocarbon Processing, 54:200, November 1975.

HIGH-PRESSURE MASS POLYMERIZATION PROCESSES

The only major commercial product made in this operation is low density polyethylene, characterized by a density of less than 0.94 g/cm^3 with a usual range of densities between 0.915 to 0.935 g/cm^3. The process is a mass addition process performed at very high pressures to accomplish the difficult polymerization of ethylene.

Data for utilities and waste streams are available for the entire operation and are presented in Table 17.

Table 17. UTILITY REQUIREMENTS AND WASTE STREAMS FOR PRODUCTION OF 454 kg OF LOW DENSITY POLYETHYLENE

Utilities	
electricity	580 kWh
natural gas	130 m^3 (5000 scf)
diesel	0.08 dm^3 (0.02 gal)
gasoline	0.20 dm^3 (0.05 gal)
water	0.992 m^3 (262 gal)
Waste Streams	
solid	4.1 kg (9.0 lb)
particulates	0.59 kg (1.3 lb)
hydrocarbons	1.4 kg (3.0 lg)
waste water	
BOD	0.10 kg (0.23 lb)
COD	0.28 kg (0.61 lb)
suspended solids	0.13 kg (0.28 lb)

Source: Sittig, Marshall. Pollution Control in the Plastics and Rubber Industry. Park Ridge, N.J., Noyes Data Corp., 1975.

There are three processes described in this operation: 1) Polymerization, 2) Separation, and 3) Final Product Preparation. Figure 6 is a process flowchart which illustrates the processing sequence.

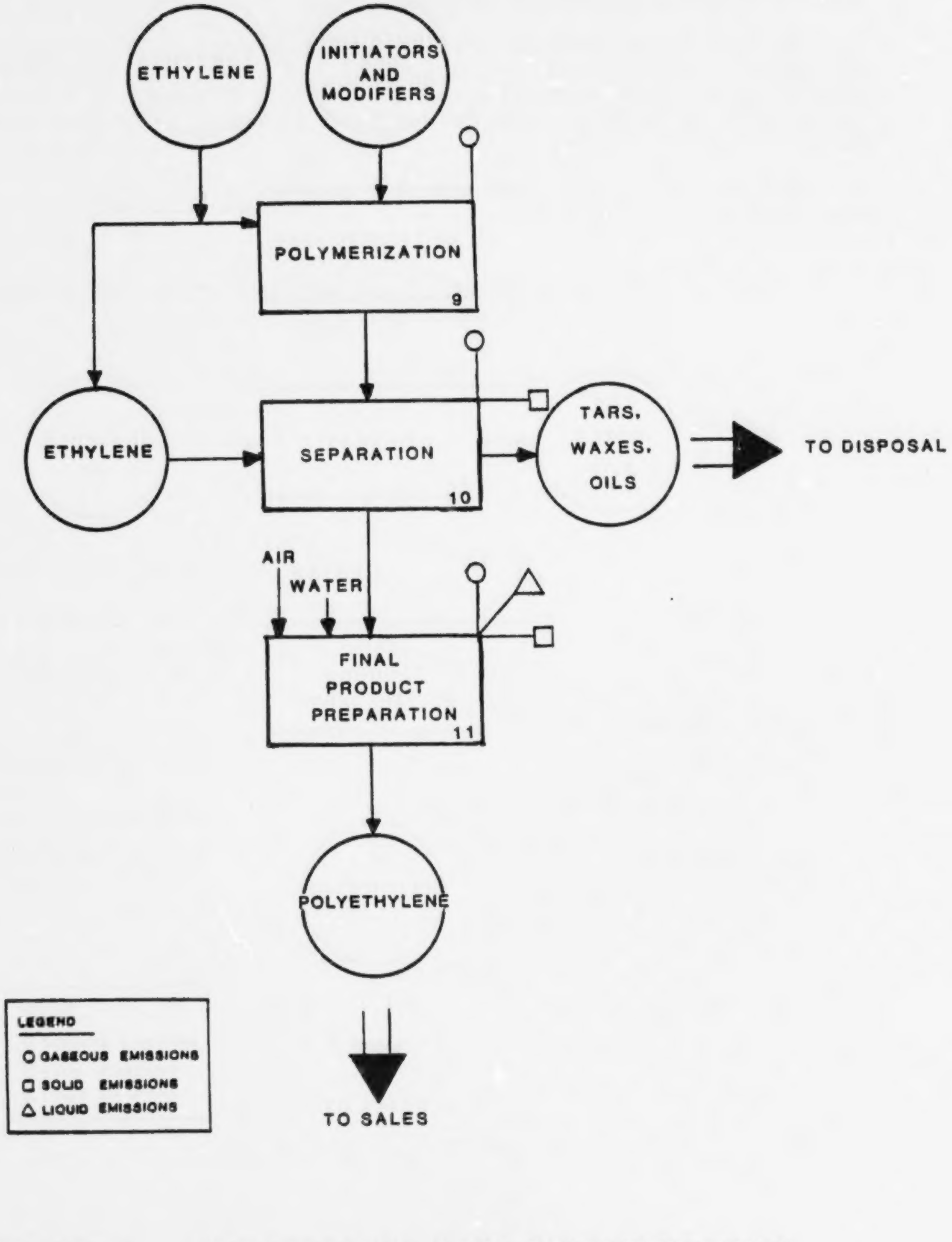

ETHYLENE
INITIATORS AND MODIFIERS
POLYMERIZATION
9
ETHYLENE
SEPARATION
10
TARS, WAXES, OILS
TO DISPOSAL
AIR
WATER
FINAL PRODUCT PREPARATION
11
POLYETHYLENE
TO SALES
LEGEND
○ GASEOUS EMISSIONS
□ SOLID EMISSIONS
△ LIQUID EMISSIONS

FIGURE 6. HIGH PRESURE MASS POLYMERIZATION

HIGH-PRESSURE MASS POLYMERIZATION PROCESS NO. 9

Polymerization

1. Function - In this process ethylene polymerizes under very high pressures to form low density polyethylene. Continuous operations are generally employed. Feed ethylene is compressed in multistage compressors to the highest practical pressure. After the first compression step, initiators and modifiers are added. Recycle ethylene joins the feedstock ethylene in the compression section.

The polymerization takes place in very high pressure kettle reactors or in tubular reactors. There may be a preheating step before the polymerization begins; some tubular reactors have temperature zones: preheat, reaction and cooling. Temperature control is accomplished through the use of cooling water and/or steam in jacketed kettles or jacketed tubes in the reactor. The reactors are generally equipped with relief vents and rupture discs.

The ethylene-polyethylene mixture leaves the reactor through a pressure control valve and is next treated in Process No. 10, Separation.

2. Input Materials - A polyethylene process licensed by Gulf Oil Chemicals Co. requires 0.917 Mg (2020 lbs) of ethylene, up to 1.8 kg (4 lbs) of initiator, and up to 1.4 kg (3 lbs) of antioxidant for producing 0.9 Mg (one ton) of pelletized polyethylene. Initiators for this process include air, oxygen, and organic peroxides. Chain transfer agents may be ketones, aldehydes, alkanes, olefins, alcohols, chlorinated compounds, or hydrogen.

3. Operating Parameters - Pressures used in the reactors are generally proprietary, but reported pressures are 0.1 to 0.3 GPa (15,000 to 45,000 psi). Reaction temperatures of up to 350°C have been reported.

First stage compression is reported to be from 2 to 31 MPa (300 to 4500 psi).

The literature describes a stainless steel tubular reactor with lengths of 30m (100 ft) and diameters of less than 2.5cm (1 inch). The preheat section of the tubular reactor raises the temperature to 100 to 200°C. Conversions in the tubular reactor are reported as 15 to 25 percent. This low conversion rate means that the recycle ethylene comprises 75 to 85 percent of the feedstream. Processes employing stirred kettle reactors have slightly higher conversions.

4. Utilities - See Table 17.

5. Waste Streams - Fugitive emissions of ethylene are minimized in the processing area because of fire and explosion hazards. The system is essentially closed, and particular attention is paid to controlling fugitive emissions at compressor seals, valves, and vents. Double mechanical seals with a purging system may be employed to remove ethylene vapors a safe distance to be vented or flared. An estimated 0.001 kg of hydrocarbon gases per kg of polyethylene produced is emitted to the atmosphere as a purge stream from the compressors. Start-up and emergency vents are normally connected to smokeless flares.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(2) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 259.

(3) Pervier, J. W., et al. Survey Reports on Atmospheric Emissions from the Petrochemical Industry, 4 Vols. EPA 450/3-73-005 a-d, Contract No. 68-02-0255. Air Products & Chemicals, Houdry Div., March 1974.

(4) Polyethylene (LD)--Gulf Oil Chems. Co. Hydrocarbon Processing, 54:184, November 1975.

(5) Raff, R. A. V. Ethylene Polymers. In: Encyclopedia of Polymer Science and Technology, Vol 6. H. F. Mark, ed. N.Y., Wiley, 1969, p. 275-332.

(6) Shreve, R. N. Chemical Process Industries, 3rd Ed. N.Y., McGraw-Hill, 1967.

(7) Unit Processes in Organic Synthesis, 5th Ed. Philip H. Groggins, ed. N.Y., McGraw-Hill, 1958, p. 943-1035.

Separation

1. Function - The liquid and gas phases of the reactor product are separated in flash tanks by pressure reduction. The gaseous phase is ethylene which is recycled; the solid phase is polyethylene which is processed further (Process No. 11). Separation usually takes place in two or more stages. Succeeding separators operate at successively lower pressures.

Ethylene gas is taken off at each stage of separation and is passed through a cooler to remove waxes and oils. The polyethylene is removed from the final separator by means of gear pumps, screw pumps, or extruders.

2. Input Materials - The feed to this process is the polymer-monomer mixture from the reactor.

3. Operating Parameters - The separators operate at pressures ranging from atmospheric to 30MPa (300 bars). No mention of operating temperature was found in the references consulted for this study.

Coolers may operate at 20 to 150°C.

4. Utilities - See Table 17.

5. Waste Streams - The tars, waxes, and oils collected in the coolers are waste materials. Disposal methods are incineration or landfilling.

Light ends from the recycle ethylene stream are vented or flared a safe distance from the processing area.

Fugitive emissions occur in this process; an estimated rate of emission is 0.010 kg of hydrocarbon gases per kg of polyethylene produced.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D.C., 1974.

(2) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 259.

(3) Makela, Robert G. and Joseph F. Malina, Jr. Solid Wastes in the Petrochemical Industry. EHE-72-14, CRWR-92. Austin, Tx., Center for Research in Water Resources, University of Texas at Austin, Aug. 1972.

(4) Pervier, J. W., et al. Survey Reports on Atmospheric Emissions from the Petrochemical Industry, 4 Vols. EPA 450/3-73-005 a-d, Contract No. 68-02-0255. Air Products & Chemicals, Houdry Div., March 1974.

(5) Polyethylene (LD)--Gulf Oil Chems. Co. Hydrocarbon Processing, 54:184, November 1975.

(6) Shreve, R. N. Chemical Process Industries, 3rd Ed. N.Y., McGraw-Hill, 1967.

(7) Sittig, Marshall. Pollution Control in the Plastics and Rubber Industry. Park Ridge, N.J., Noyes Data Corp., 1975.

(8) Unit Processes in Organic Synthesis, 5th Ed. Philip H. Groggins, ed. N.Y., McGraw-Hill, 1958, p. 943-1035.

Final Product Preparation

1. Function - The polyethylene material is extruded generally in a screw-type extruder equipped with one or more devolatilization chambers. The strands of polymer are usually cooled in a water bath, chopped into pellets by a pelletizer, and then screened. The cooling water is recycled.

The screened pellets are dried. The specific type of drier was not specified in the literature consulted for this study. The polyethylene pellets are generally conveyed by air to various storage and processing points.

2. Input Materials - Molten polyethylene, makeup cooling water, and air for conveying the pellets are input materials to this process.

3. Operating Parameters - Large extruders can process nearly 0.5Mg (1000 lb) of polymer per hour at linear velocities of 2.5 m/sec (500 ft/min).

4. Utilities - See Table 17.

5. Waste Streams - A waste-water stream containing polymer fines may be generated in this process, depending on the operations of the plant. If recycle of polymer cooling water is practiced, a blowdown or purge stream results.

The drying step may generate particulate emissions and a waste-water stream depending on the type in use. No reference to the type of drier used for low density polyethylene was made in the literature consulted for this study.

Vents from the air conveying systems are sources of residual ethylene and particulate emissions. Recommended methods for particulate control are cyclones and bag filters used together. An estimated 0.0003 kg of particulates and 0.005 kg of hydrocarbons are emitted in materials handling per kg of polyethylene produced.

Off-grade and scrap polyethylene form a solid waste stream which is disposed of by incineration or landfilling.

Vents from pellet storage bins also have the potential for atmospheric hydrocarbon emissions. One plant operator responding to an EPA questionnaire reported 0.0039 kg of ethylene emitted from the top of pellet storage bins per kg of polyethylene produced.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Billmeyer, Fred W., Jr. Textbook of Polymer Science, 2nd Ed. N.Y., Wiley, 1971.

(2) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(3) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 259.

(4) Polyethylene (LD)--Gulf Oil Chems. Co. Hydrocarbon Processing, 54:184, November 1975.

(5) Raff, R. A. V. Ethylene Polymers. In: Encyclopedia of Polymer Science and Technology, Vol 6. H. F. Mark, ed. N.Y., Wiley, 1969, p. 275-332.

(6) Shreve, R. N. Chemical Process Industries, 3rd Ed. N.Y., McGraw-Hill, 1967.

(7) Unit Processes in Organic Synthesis, 5th Ed. Philip H. Groggins, ed. N.Y., McGraw-Hill, 1958, p. 943-1035.

SOLUTION POLYMERIZATION PROCESSES

Solution polymerization is an operation in which a solvent is added to the reaction mixture which dissolves the monomer, the polymer, and the initiating agent. The viscosity of the resultant solution is lower than that of a bulk polymerization reaction mixture. The lower viscosity allows better heat transfer and easier agitation. One of the disadvantages of this processing method is the necessity for solvent recovery. Another is the slower reaction rates due to dilution by the solvent.

Polymerizations using water as a solvent are included in this operation. The principal polymers made by this process are styrene polymers and copolymers, α-methylstyrene copolymers, polyacrylic acid, polymethacrylic acid, polyacrylamide, and poly(vinyl pyrrolidone) and copolymers; the last four are generally formed in aqueous media.

Two process descriptions are presented for this operation: 12) Polymerization and 13) Solvent Recovery. They are shown in Figure 7.

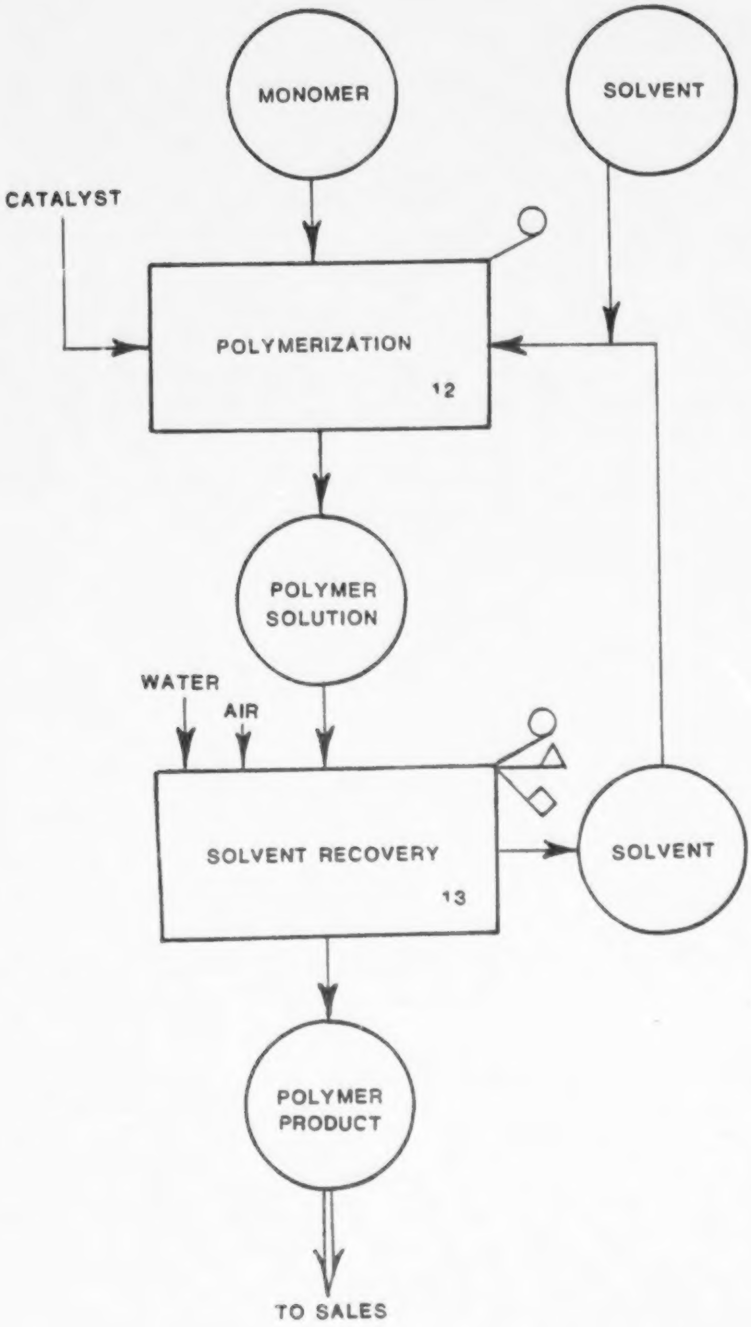

MONOMER
SOLVENT
CATALYST
POLYMERIZATION
12
POLYMER SOLUTION
WATER
AIR
SOLVENT RECOVERY
13
SOLVENT
POLYMER PRODUCT
TO SALES

FIGURE 7. SOLUTION POLYMERIZATION

LEGEND

○ GASEOUS EMISSIONS

☐ SOLID EMISSIONS

△ LIQUID EMISSIONS

Polymerization

1. Function - The monomer(s) and initiator are combined with a suitable solvent. If the catalysts used are subject to poisoning problems, a feed purification procedure such as distillation is necessary. Vertical vessels with turbine agitators may be used for polymers with viscosities up to 5 Pa·s (5000 cp). Anchor-type agitators are chosen for polymers with viscosities up to 100 Pa·s (100,000 cp). A series of tubular agitated reactors constructed of aluminum or stainless steel is reportedly used in polystyrene production by the solution polymerization method.

Temperature control is often accomplished by circulating water in the vessel jackets and by the addition of cold solvent. Some polymers may be cooled by reflux cooling or by the use of an external flash loop. The dissolved polymerized material from the reactor is treated in the Solvent Recovery Process (No. 13).

2. Input Materials - Monomer materials include styrene, α-methylstyrene, acrylic acid, methacrylic acid, acrylamide, N-vinyl-2-pyrrolidone, and polymerizable vinyl comonomers.

Hydrocarbon solvents are used in some systems, water in others. Ethylbenzene is often used in making polystyrene.

3. Operating Parameters - The following data were found in the literature for solution polymerization processes.

For copolymerization of N-vinyl-2-pyrrolidone
solvent: alcohol or benzene
temperature: 50 to 75°C
catalyst: benzoyl peroxide, lauroyl peroxide or azobis(isobutyronitrile)

For homopolymerization of N-vinyl-2-pyrrolidone
solvent: water
temperature: 50 to 80°C
catalyst: hydrogen peroxide and ammonia or azobis(isobutyronitrile)

For styrene-acrylonitrile copolymers
solvent: ethylbenzene or toluene
temperature: 150°C
reaction rate: 27%/hr

4. Utilities - Data were not available in the literature consulted for this study.

5. Waste Streams - The reactor is essentially a closed system, but fugitive emissions of hydrocarbon solvent and monomer materials may occur at pump and compressor seals, pipe flanges, vents, and other points in the equipment. Reactor vents in polystyrene plants are reportedly the source of 0.00334 kg of hydrocarbon emissions to the atmosphere per kg of polystyrene produced. An additional 0.00065 kg of hydrocarbons per kg of polystyrene product is emitted in the feed preparation step.

6. EPA Source Classification Code - Polyprod. General 3-018-01-02

7. References:

(1) Billmeyer, Fred W., Jr. Textbook of Polymer Science, 2nd Ed. N.Y., Wiley, 1971.

(2) Environmental Protection Agency. Effluent Guidelines Division. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Polymers Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-75-036-b. Washington, D. C., January 1975.

(3) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 265.

(4) Pervier, J. W., et al. Survey Reports on Atmospheric Emissions from the Petrochemical Industry, 4 Vols. EPA 450/3-73-005 a-d, Contract No. 68-02-0255. Air Products & Chemicals, Houdry Div., March 1974.

(5) Schlegel, Walter F., Design and Scaleup of Polymerization Reactors. Chemical Engineering, 79:88-95, 20 March 1972.

Solvent Recovery

1. Function - Solvent is recovered from the contents of the reactor for recycle in various ways. This may be accomplished by flashing or evaporation followed by devolatilization. Equipment used for the first step of removing up to 90 percent of the volatile materials from the polymer includes vacuum drum driers, spray driers, multiple-vent extruders, and thin film evaporators. Devolatilization removes the remaining volatiles down to about 0.1 to 0.5 percent and is usually accomplished in an extruder equipped with evacuation zones. The solvent recovered from the driers, evaporators, and extruders is recycled to the reactor.

Another method of separating solvent from polymer involves "crumbing." Spraying of the polymer solution into vigorously agitated hot water causes the solvent to evaporate, leaving small particles of polymer suspended in the water. The polymer solution may be premixed with steam or hot water before it is injected into the agitated vessel. The slurry of polymer in water must then be subjected to liquid-solid separation methods. Filtration and centrifugation employing belt filters, perforate basket centrifuges, solid-bowl centrifuges, or pusher centrifuges are generally used.

The remaining water must be removed by drying. Although no information as to the type of dryer used for these specific polymers was found in the literature consulted, rotary driers are quite common in the polymer industry.

Extruded polymer is pelleted, blended and packaged. Pneumatic conveying systems often accomplish transport of the pellets.

2. Input Materials - The polymerization reactor contents form the feed material to this process. Hot water and steam may be inputs if crumbing operations are used. Air may be required for drying operations. Direct drying with air requires 0.2 to 0.3 m^3/min (8 to 10 ft^3/min) of air to remove 0.5 kg (1 lb) of water.

3. Operating Parameters - Operating conditions for rotary driers are discussed in Process No. 7.

Spray driers may operate under positive or negative pressures.

4. Utilities - Table 16 in Process No. 7 summarizes utilities for various types of centrifuges. Also discussed is the power requirement for rotary driers.

5. Waste Streams - A liquid waste stream may result from the centrifugation or filtration procedures if crumbing is used. Recycle methods may keep this volume to a minimum.

Flashing, vacuum drying, and devolatilization may result in fugitive emissions of hydrocarbon solvent at vents, valves, and seals. Polystyrene manufacturing operations reportedly emit 0.00184 kg of hydrocarbon per kg of polystyrene produced in this manner.

Volatile materials may be emitted from the driers along with dust particles. Dust collection equipment usually consists of cyclones and bag filters; wet scrubbers may be used. If only cyclones are used, an estimated 1 percent of the plant capacity will be lost as dust. Pneumatic conveying systems also contribute to the particulate emissions. An estimated 0.00010 kg of polystyrene particulates per kg polystyrene produced are discharged in this manner in the manufacture of polystyrene. Off-spec and waste resin form a solid waste stream amounting to as much as 12 Mg/day (26,000 lb/day) of polystyrene for a plant with a capacity of 136 Gg/yr (150,000 tons/yr).

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Chemical Engineers' Handbook, 4th Ed. Robert H. Perry, ed. N.Y., McGraw-Hill, 1963.

(2) Environmental Protection Agency, Effluent Guidelines Division. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Polymers Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-75/036-b. Washington, D. C., Jan. 1975.

(3) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 265.

(4) Oringer, Kenneth. Current Practice in Polymer-Recovery Operations. Chemical Engineering, 79:29-106, 20 March 1972.

(5) Pervier, J. W., et al. Survey Reports on Atmospheric Emissions from the Petrochemical Industry, 4 Vols. EPA 450/3-73-005 a-d, Contract No. 68-02-0255. Air Products & Chemicals, Houdry Div., March 1974.

PARTICLE FORM POLYMERIZATION PROCESSES

The Phillips Particle Form Process (also called the Phillips slurry process to avoid confusion with the Phillips solution process) is presented in this operation. This process accounts for production of more high-density polyethylene than all of the other processes combined. Commercially available products have densities ranging from 0.939 to 0.964 and molecular weights of 25,000 to 1,000,000. Ethylene-olefin copolymers are also produced by this process. This operation is similar to the Ziegler operation in that it employs a metal catalyst to produce high-density polyethylene at relatively low pressures. An improvement over the Ziegler polymerization is found in the elimination of catalyst recovery for most uses; the small amounts of catalyst remain in the polymer.

The descriptions in the literature consulted for this study were often vague with regard to this type of polymerization. Two process descriptions were written as definitively as possible using the information at hand: 14) Polymerization, and 15) Polymer Recovery. Figure 8 is a flow sheet for the Particle Form Polymerization Operation.

Some data on utilities and waste streams were available for the entire operation of producing high-density polyethylene although the type of commercial process is not specified. These data are included in Table 18.

Table 18. UTILITY REQUIREMENTS AND WASTE GENERATION FOR PRODUCTION OF 454 kg OF HIGH DENSITY POLYETHYLENE[a]

UTILITIES	
electricity	390 kWH
natural gas	0.067m (2.5 scf)
water	6.74m (1780 gal)
WASTES	
solid	1.1 kg (2.4 lb)
gaseous (hydrocarbon)	2.3 kg (5.0 lb)
liquid	
BOD	0.17 kg (0.37 lb)
COD	0.93 kg (2.04 lb)
suspended solids	0.28 kg (0.62 lb)

[a] commercial process not identified

Source: Sittig, Marshall. Pollution Control in the Plastics and Rubber Industry. Park Ridge, N. J., Noyes Data Corp., 1975.

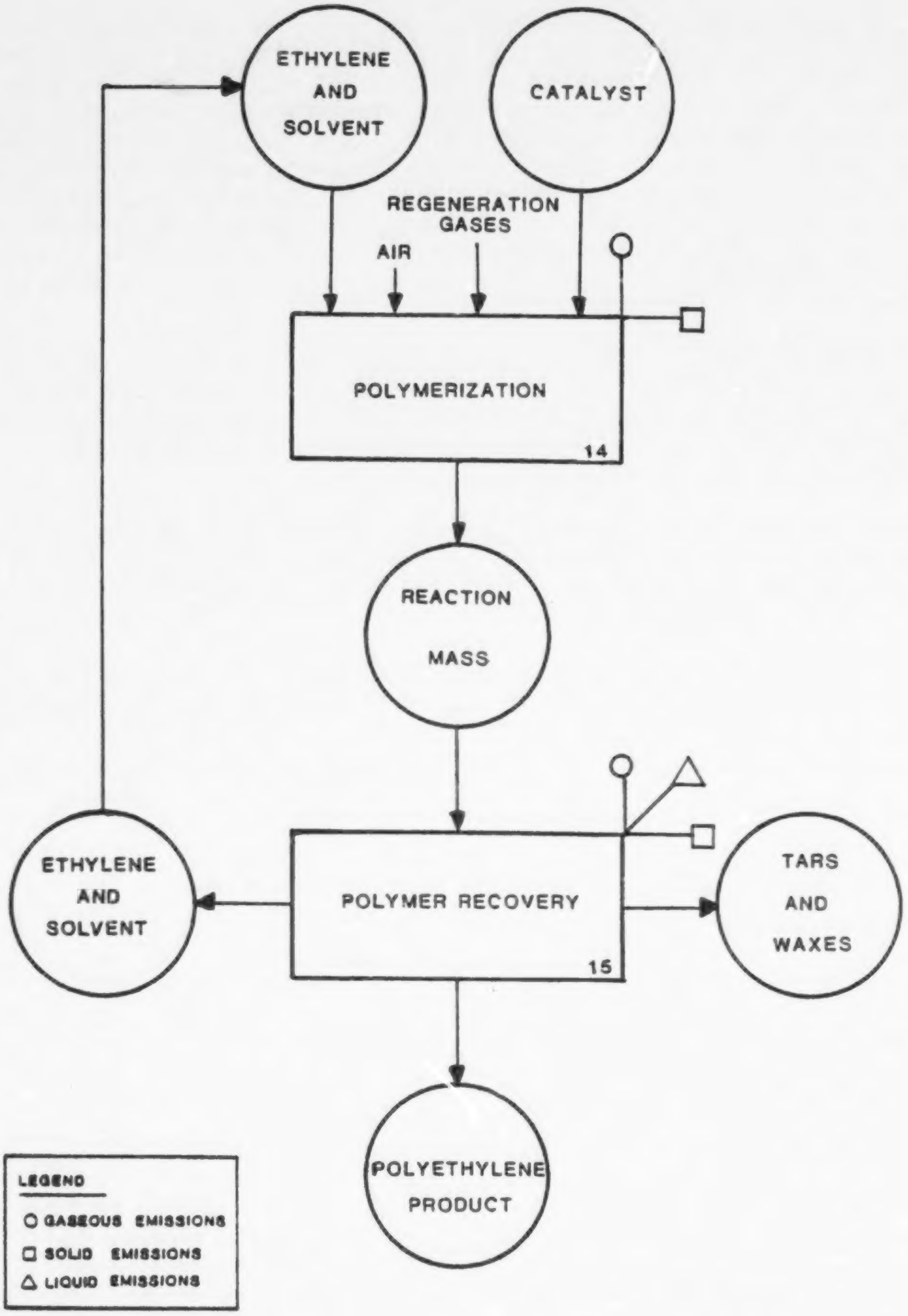

ETHYLENE AND SOLVENT
CATALYST
REGENERATION GASES
AIR
POLYMERIZATION
14
REACTION MASS
ETHYLENE AND SOLVENT
POLYMER RECOVERY
15
TARS AND WAXES
POLYETHYLENE PRODUCT
LEGEND
○ GASEOUS EMISSIONS
□ SOLID EMISSIONS
△ LIQUID EMISSIONS

FIGURE 8. PARTICLE FORM POLYMERIZATION

Polymerization

1. Function - Polyethylene is produced in a continuous process in stirred or loop-type reactors. Catalyst, hydrocarbon solvent, and monomer are introduced into the reactor which is agitated mechanically or by convection. Temperature control may be provided by water circulation through cooling jackets. Both the ethylene feed and the catalyst must be treated before they are used. The catalyst must be activated by passing hot air over it; the ethylene feed is treated in a molecular sieve bed for removal of catalyst poisons such as carbon dioxide, oxygen, and water. A polymer stream is continuously withdrawn as input to polymer recovery, Process No. 15.

2. Input Materials - 99+ percent ethylene is required as a feed to this process. Two hydrocarbon solvents mentioned in the consulted literature were pentane and cyclohexane. One description of the Phillips process listed feed requirements of 0.95 Mg (2100 lb) of ethylene and 54 kg (119 lb) of cyclohexane per 0.90 Mg (one ton) of product high-density polyethylene. Ninety-five percent and higher conversion rates per pass are claimed. Hot air is required for catalyst activation, and a stream of regeneration gas is required for the molecular sieve beds.

Table 19 lists input requirements for ethylene-olefin copolymers of various compositions.

TABLE 19. RATIOS OF FEED MATERIALS FOR VARIOUS COMONOMERS OF ETHYLENE

Feed[a]	Product[a] Ethylene-propylene copolymer	Ethylene-1-butene copolymer
5	12	9
10	19	15
15	25	21
20	32	26
30	44	39

[a] weight ratio of ethylene to comonomer

Input materials for an ethylene-propylene copolymer with a density of 0.930 are cited as 80/20 volume % ethylene/propylene in a 1% solution of 99% 2,2,4-trimethylpentane.

3. Operating Parameters - Conditions which may be varied to produce commercial products are temperature, pressure, feed concentration, and catalyst preparation method. Approximate operating conditions for high-density polyethylene are as follows:

temperature: 140°C
pressure: 3 MPa (30 atmospheres)
catalyst: hexavalent chromium oxide on silica-alumina

The catalyst is activated by calcining in air at 400 to 850°C. A typical operating temperature for an ethylene-propylene copolymer with a density of 0.93 is 115°C.

4. Utilities - See Table 18.

5. Waste Streams - Two potential sources of particulate emissions exist in this process. Catalyst activation, accomplished by blowing hot air, may result in emission of catalyst fines. Regeneration of molecular sieve beds by purging with a gas stream may result in silica gel particulate emissions to the atmosphere.

Start-up and emergency vents and flares may contribute intermittent gaseous emissions of pollutants to the atmosphere. Purging of the molecular sieve beds may be accomplished with a hydrocarbon gas stream. The composition was not clearly stated in the sources consulted for this study.

Fugitive emissions may occur at valves, seals, and flanges. An estimated 0.0200 kg of hydrocarbons are emitted per kg of polyethylene produced in this manner.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Caldwell, E. D. High-Molecular-Weight Ethylene Polymers. In: Encyclopedia of Polymer Science and Technology, Vol 6. H. F. Mark, ed. N.Y., Wiley, 1967, p. 332-38.

(2) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(3) Friedlander, Herbert N. Ethylene-1-Olefin Copolymers. In: Encyclopedia of Polymer Science and Technology, Vol 6. H. F. Mark, ed. N.Y., Wiley, 1967, p. 338-86.

(4) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(5) Pervier, J. W., et al. Survey Reports on Atmospheric Emissions from the Petrochemical Industry, 4 Vols. EPA 450/3-73-005 a-d, Contract No. 68-02-0255. Air Products & Chemicals, Houdry Div., March 1974.

(6) Polyethylene--Phillips Petroleum Co. Hydrocarbon Processing, 54:187, November 1975.

(7) Sittig, Marshall. Pollution Control in the Plastics and Rubber Industry. Park Ridge, N.J., Noyes Data Corp., 1975.

Polymer Recovery

1. Function - This process isolates and finishes the polymer product. A stream of polymer from the reactor enters a flash drum in which a reduction in pressure produces an overhead stream containing solvent, ethylene, waxes, and light gases. This overhead stream must be purified before the ethylene and solvent may be recycled. It is assumed that this purification is accomplished by distillation with the light gases vented or flared and the waxes sent to incineration or disposal. There also may be a water scrubber to remove polymer fines from the overhead stream.

The polymer is taken continuously from the bottom of the flash drum to be dried. One account of this type of processing specifies a rotary steam tube drier which supplies indirect heat. The dry polyethylene may be blended with colorizers and other additives in a Banbury mixer or in an extruder. The extruded strands are usually water cooled before they are chopped into pellets, dried and stored. Air conveying is the usual method of transferring polymer to various processing and storage points in the plant, but at least one plant uses a water system for some of its conveying.

Ultra-high molecular weight polymers require special extruding equipment that has no screw. The details are proprietary.

2. Input Materials - The reaction product from Process No. 14, steam for the drier, air for conveying, and possibly water for cooling and conveying are input materials. Approximately 0.5 to 1.4 kg (1 to 3 lb) of 0.96 MPa (125 psig steam) is required per 0.5 kg (one pound) of dry product in the rotary steam tube dryer.

3. Operating Parameters - Vertical vessels are commonly used as flash tanks. Pressures encountered in Banbury mixers are generally 0.10 to 0.14 MPa (15 to 20 psi). Extrusion temperatures for polyethylene are generally in the range of 150 to 260°C (300 to 500°F).

4. Utilities - A No. 11 Banbury mixer operating at 20 rpm and processing 0.25 $m^3/10$ min (9 $ft^3/10$ min) consumes 190 kW (250 hp). The same mixer operating at 40 rpm processing 0.25 $m^3/5$ min (9 $ft^3/5$ min) requires 370 kW (500 hp).

5. Waste Streams - The light gases from the solvent and monomer recovery purification step are vented or flared to form one of the main sources of gaseous emissions in this operation. An estimated 0.0020 kg of hydrocarbon per kg of polyethylene produced is emitted to the atmosphere in this manner.

Water scrubbers are sometimes used to scrub polymer fines from the flashed gases. This results in a waste-water stream which contains hydrocarbons and polymer fines.

Pneumatic conveyors and associated vents are a source of hydrocarbon and particulate emissions. An estimated 0.003 kg of hydrocarbons and 0.0010 kg of particulates are emitted per kg of polyethylene produced.

Cooling water for extruded strands must be treated for solids removal before disposal. One plant operator in answering an EPA questionnaire reported a discharge rate of 0.38 to 0.57 m^3/min (100 to 150 gal/min) of waste water from cooling and pellet transferring operations.

Non-specification product is disposed of by landfilling or incineration. Reported disposal rates are 90 to 900 Mg/yr (0.2 to 2 million lb/yr). Waxes removed from the recycle stream are disposed of in a similar manner. A producer of 80 Gg/yr (90,000 tons/yr) capacity reported a production rate of 90 Mg/yr (0.2 million lb/yr) of waxes. The production rate of waxes varies considerably from plant to plant.

6. **EPA Source Classification Code** - Polyprod. General 3-01-018-02

7. References -

(1) Chemical Engineers' Handbook, 4th Ed. Robert H. Perry, ed. N.Y., McGraw-Hill, 1963.

(2) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(3) Oringer, Kenneth. Current Practice in Polymer-Recovery Operations. Chemical Engineering, 79:29-106, 20 March 1972.

(4) Pervier, J. W., et al. Survey Reports on Atmospheric Emissions from the Petrochemical Industry, 4 Vols. EPA 450/3-73-005 a-d, Contract No. 68-02-0255. Air Products & Chemicals, Houdry Div., March 1974.

(5) Polyethylene--Phillips Petroleum Co. Hydrocarbon Processing, 54:187, November 1975.

POLYOLEFINS POLYMERIZATION (ZIEGLER) PROCESSES

The Ziegler process is characterized by the use of a metal alkyl or alkyl halide catalyst which is recovered from the polymer and by the precipitation of the polymer as it is formed. The product of the reaction is a slurry of high-density polyolefins. It is similar to the Phillips process in that low or moderate pressures are required as opposed to the high pressures required for manufacturing low-density polyethylene. Polymers produced by this operation include high-density polyethylene with a density range of 0.940 to 0.965 g/cm^3 and a molecular weight of over 1,000,000; polypropylene; polybutene; and various copolymers.

Figure 9 illustrates the three processes described in this operation: 16) Polymerization, 17) Catalyst and Solvent Removal, and 18) Product Preparation. A general description of Ziegler-type commercial operations is intended in this treatment; there are many variations in existing plants. Quantitative data concerning utilities and waste streams were not always available in the literature consulted for this study. Table 18 gives information concerning production of high-density polyethylene by an unspecified method. Table 20 lists utility requirements for two commercial Ziegler-type polyethylene processes along with one commercial process for production of polypropylene using a Ziegler catalyst. Utility requirements may vary widely from plant to plant.

Table 20. UTILITY REQUIREMENTS FOR ZIEGLER-TYPE POLYOLEFINS PROCESSES[a]

Utilities	Polyethylene	Polyethylene	Polypropylene
electricity (kWh)	700	490	200
steam (kg)	2,200	2,400	3,340
cooling water (m^3)	250	180	250

[a] values are for 1000 kg of product.

Source: Polyethylene (HD) - Snamprogetti. Hydrocarbon Processing, 54:188, November 1975.

Polyethylene (HD) - Veba-Chemie AG. Hydrocarbon Processing, 54:191, November 1975.

Polypropylene - Hoechst AG. Hydrocarbon Processing, 54:196, November 1975.

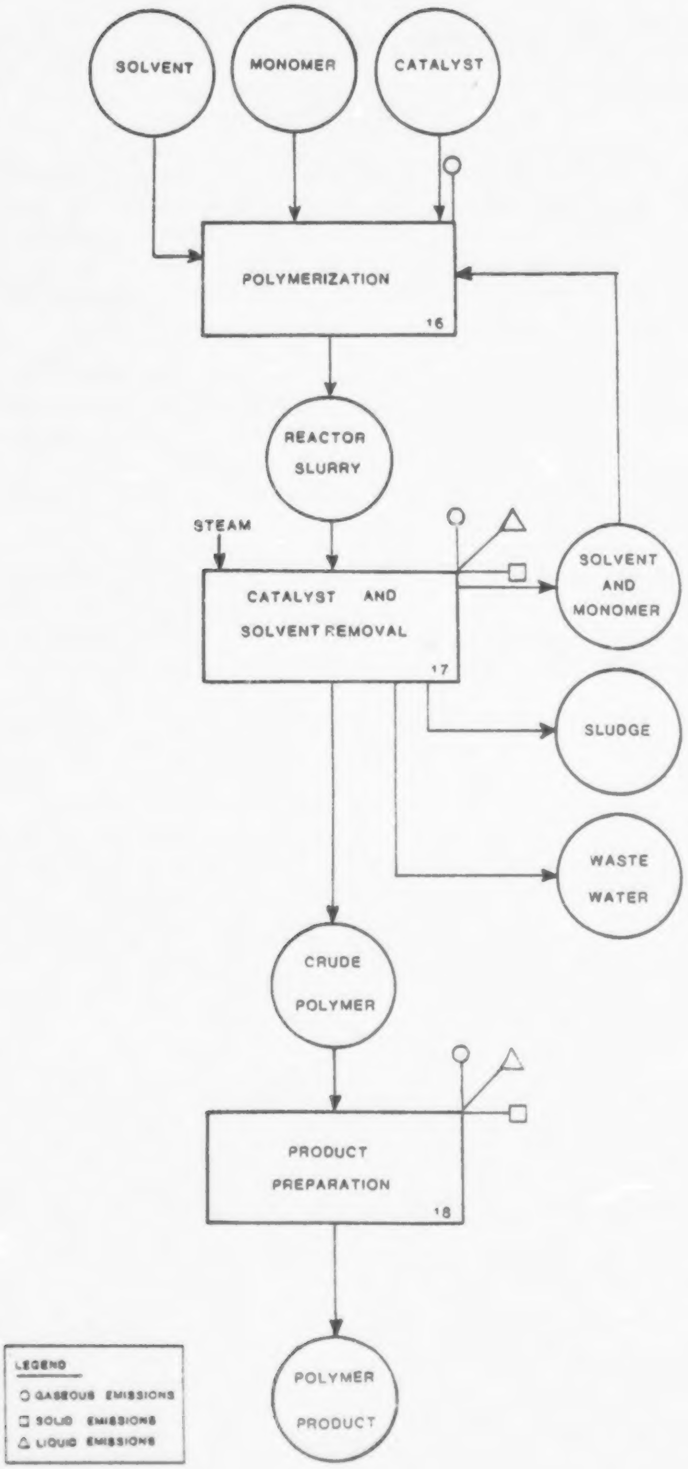

SOLVENT
MONOMER
CATALYST
POLYMERIZATION
16
REACTOR SLURRY
STEAM
CATALYST AND SOLVENT REMOVAL
17
SOLVENT AND MONOMER
SLUDGE
WASTE WATER
CRUDE POLYMER
PRODUCT PREPARATION
18
POLYMER PRODUCT
LEGEND
○ GASEOUS EMISSIONS
□ SOLID EMISSIONS
△ LIQUID EMISSIONS

FIGURE 9. POLYOLEFIN PRODUCTION (ZIEGLER)

Polymerization

1. Function - In this process ethylene and/or other olefins are polymerized to form a high density product. Catalyst preparation is usually accomplished by combining a transition metal halide with a metal alkyl or metal alkyl chloride in an anhydrous hydrocarbon solvent. Poisoning of the catalyst is usually inhibited by neutralization of sulfur- and oxygen-containing compounds with alkylaluminum compounds.

Monomer, catalyst, and hydrocarbon solvent are added to the stirred kettle reactor; the process may be a batch-type or continuous. The polymer precipitates as it forms, producing a polymer slurry. Temperatures and pressures encountered are generally lower than for the other two polyethylene polymerization processes. The product slurry is then treated in process No. 17 for catalyst and solvent removal.

2. Input Materials - Catalyst components, hydrocarbon solvent, chain transfer agents, and monomers are input materials to this process. Useful chain transfer agents are hydrogen and alkyl-zinc compounds. Approximately 1040 kg of ethylene are required to make 1000 kg of dry polyethylene power.

3. Operating Parameters - Temperatures for Ziegler-type polymerizations are reported to be below 100°C, usually 20 to 80°C. Pressures are reported as 0.1 to 2.5 MPa (1 to 25 atm).

Temperature, agitation rate, and specific catalyst components control the activity and selectivity of the catalyst. Titanium trichloride is reported to be the most widely used catalyst; the most frequently named metal alkyl compounds are ethyl- and isobutyl-aluminum hydride and chlorides and trialkyl aluminum compounds. The ratios used are generally 1 to 4 moles of alkyl metal compound per mole of transition metal compound.

4. Utilities - See Table 20.

5. Waste Streams - The compressor vent for the recycle stream in a polyethylene plant is reported to emit 18 kg (40 lb) ethylene, 0.9 kg (2 lb) ethane, ano 20 kg (45 lb) hexane per 0.9 Mg (one ton) of product.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Environmental Protection Agency, (Office of Air and Water Programs. Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D.C., 1974.

(2) Friedlander, Herbert N. Ethylene-1-Olefin Copolymers. In: Encyclopedia of Polymer Science and Technology, Vol 6. H. F. Mark, ed. N.Y., Wiley, 1967, p. 338-386.

(3) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MCR-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(4) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 284.

(5) Polyethylene--Phillips Petroleum Co. Hydrocarbon Processing, 54:187, November 1975.

(6) Raff, R. A. V. Ethylene Polymers. In: Encyclopedia of Polymer Science and Technology, Vol 6. H. F. Mark, ed. N.Y., Wiley, 1969, p. 275-332.

(7) Unit Processes in Organic Synthesis, 5th Ed. Philip H. Groggins, ed. N.Y., McGraw-Hill, 1958, p. 943-1035.

Catalyst and Solvent Removal

1. Function - The catalyst and solvent are removed from the polymerization product (Process No. 16) in this process to form a crude polymer. If the polymerization takes place under pressure, the pressure is reduced in a flash tank. Volatilized monomer and solvent are recovered for recycle.

The polymer is washed with an aqueous alcohol solution which dissolves and removes the catalyst. The catalyst is precipitated in the form of metal oxides which will settle to form a sludge. The effluent is sent to a distillation unit in which alcohol is recovered for recycle, while aqueous waste containing catalyst fines and alcohol is discharged.

Solvent is removed from the polymer by steam stripping. The solvent is distilled for recycle, producing a waste stream containing water and heavy ends. The aqueous polymer slurry is subjected to centrifugation or filtration to produce crude crumb which is further treated in Process No. 18.

2. Input Materials - The reactor product, steam, and make-up alcohol are required for this process.

3. Operating Parameters - None were available in the information consulted for this study.

4. Utilities - See Table 20.

5. Waste Streams - The largest raw waste load from the plant is reported to be the aqueous phase from the alcohol distillation unit. The waste water contains alcohol and metal oxide fines. Consolidation of the metal oxide sludge has posed a solid waste disposal problem in the industry. It is assumed that the tower bottoms from solvent distillation form a waste stream, but no indication was found of treatment or disposal method. Fugitive gaseous emissions of alcohol and solvent result from distillation.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1/74-010-a. Washington, D.C., 1974.

(2) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(3) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 284.

(4) Polyethylene--Phillips Petroleum Co. Hydrocarbon Processing, 54:187, November 1975.

(5) Sittig, Marshall. Pollution Control in the Plastics and Rubber Industry. Park Ridge, N.J., Noyes Data Corp., 1975.

Production Preparation

1. Function - The crude polymer crumb is dried, extruded, and pelletized to form the final product.

One source indicates the use of rotary steam tube driers for drying the polymer crumb; it is assumed that this type of equipment would be used for drying the pellets as well. It is probable that the extrusion and pelletizing methods are very similar to those of the Particle Form and Low Density Operations. The dried polymer crumb is processed in an extruder. A single helical screw is most often used for polyethylene. Ultra-high molecular weight polyolefins require special equipment. The strands are water-cooled and pelleted. Separation occurs by screening. Pellets are then dried for storage. Water and/or air conveying is used for transporting pellets to various processing points in the plant.

2. Input Materials - Polymer crumb, cooling water, steam, and air (and/or water) for conveying are input materials to this process. An estimated 0.5 to 1.4 kg (1 to 3 lb) of 0.96 MPa (125 psig) steam are required per 0.5 kg (one pound) of dry product in the rotary steam tube dryer.

3. Operating Parameters - Extrusion temperatures for polyethylene are generally in the range of 150 to 260°C (300 to 500°F).

4. Utilities - See Table 20.

5. Waste Streams - No quantitative data were available in the sources consulted for Ziegler-type operations, but they are assumed to be essentially the same as those for the Particle Form Operation (Process No. 15). Pneumatic conveyors and associated vents are a source of hydrocarbon and particulate emissions.

Waste water from cooling and pellet transfer operations contains polyolefin particles which must be separated before disposal. Solid waste is composed of non-specification and excess product which is disposed of by incineration or landfilling. The dryers may be a source of liquid and gaseous emissions.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Chemical Engineers' Handbook, 4th Ed. Robert H. Perry, ed. N.Y., McGraw-Hill, 1963.

(2) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(3) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N. Y., Van Nostrand Reinhold, 1974, p. 284.

(4) Pervier, J. W., et al. Survey Reports on Atmospheric Emissions from the Petrochemical Industry, 4 Vols. EPA 450/3-73-005 a-d, Contract No. 68-02-0255. Air Products & Chemicals, Houdry Div., March 1974.

(5) Raff, R. A. V. Ethylene Polymers. In: Encyclopedia of Polymer Science and Technology, Vol 6. H. F. Mark, ed. N.Y., Wiley, 1969, p. 275-332.

(6) Sittig, Marshall. Pollution Control in the Plastics and Rubber Industry. Park Ridge, N.J., Noyes Data Corp., 1975.

PHENOLIC RESIN PRODUCTION PROCESSES

This operation treats the formation of resins by polymerization of phenol and formaldehyde. There are two major types: resols (one-stage resins) and novolaks (two-stage resins). The resols are formed in an alkaline medium with an excess of formaldehyde and are marketed as thermosetting resins, bonding resins, varnishes, and laminates. Novolaks are formed in an acid medium deficient in formaldehyde. These thermoplastic resins require mixing with formaldehyde or a formaldehyde donor such as hexamethylene tetramine to produce a thermosetting product. Thermosetting resin powders, varnishes, and laminates are novolak products.

Waste stream information is available for production of phenolic resins in general. The type of resin produced is not specified, and the waste load for the entire plant is included, as summarized in Table 21.

Table 21. WASTE STREAM INFORMATION FOR PRODUCTION OF PHENOLIC RESINS

Dry solids to disposal	10-15 kg/Mg product
Reported waste water flow	10-20 m^3/Mg product
BOD	15-51 kg/Mg product
COD	90-64 kg/Mg product
Suspended Solids	0.7-7 kg/Mg product
Phenols (concentration in waste water)	5-7 wt %
Formaldehyde (concentration in waste water)	5-8 wt %
Methanol (concentration in waste water)	5-7 wt %

Source: Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D.C., 1974.

Sittig, Marshall. Pollution Control in the Plastics and Rubber Industry. Park Ridge, N.J., Noyes Data Corp., 1975.

Four process descriptions are included in this operation to describe the production of the two types of products: 19) Polymerization (Resols), 20) Product Preparation (Resols), 21) Polymerization (Novolaks), and 22) Product Preparation (Novolaks). Figure 10 is a flow sheet illustrating the interrelation of the four processes treated in this operation.

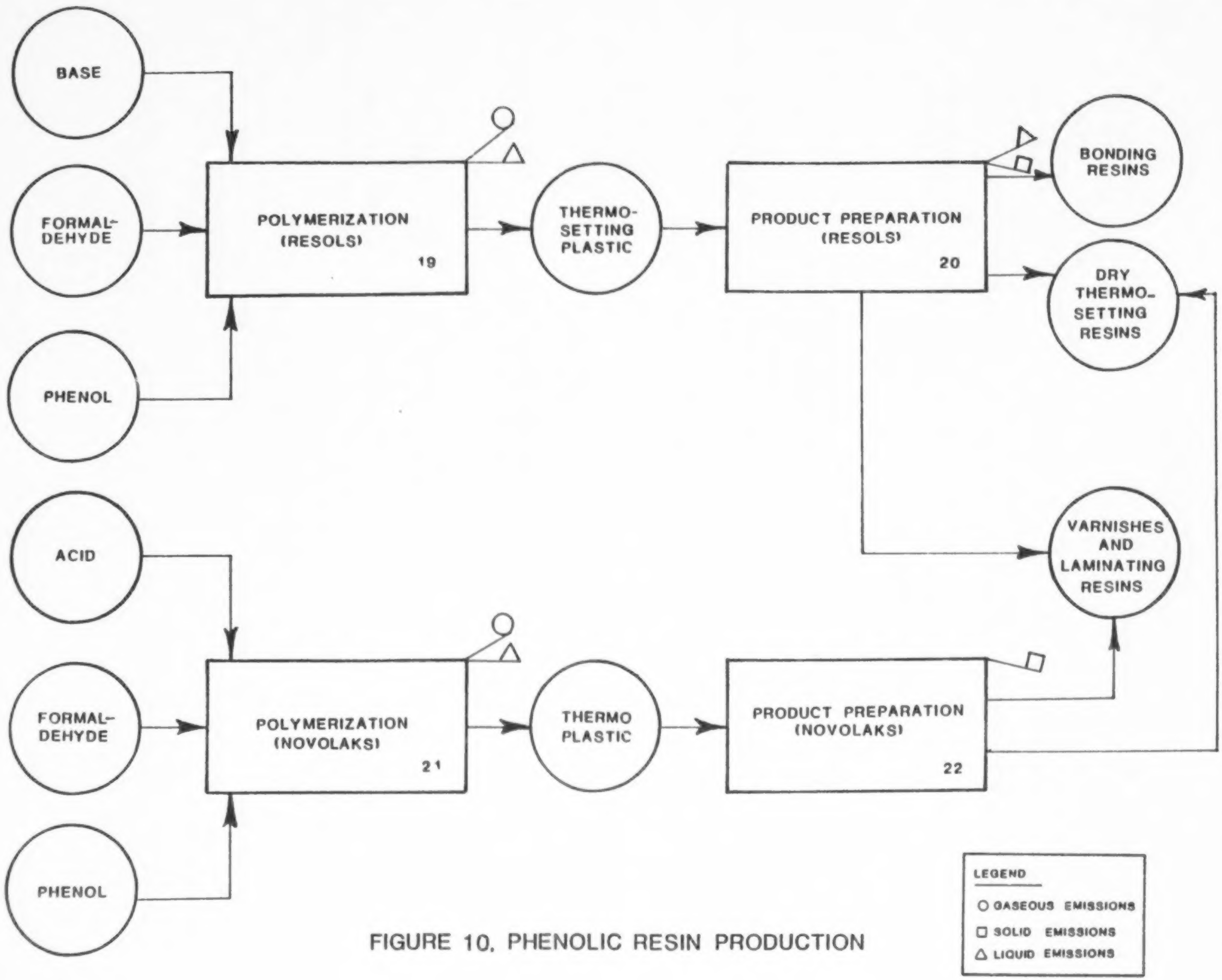

BASE
FORMAL-DEHYDE
PHENOL
POLYMERIZATION (RESOLS)
19
THERMO-SETTING PLASTIC
PRODUCT PREPARATION (RESOLS)
20
BONDING RESINS
DRY THERMO-SETTING RESINS
ACID
FORMAL-DEHYDE
PHENOL
POLYMERIZATION (NOVOLAKS)
21
THERMO PLASTIC
PRODUCT PREPARATION (NOVOLAKS)
22
VARNISHES AND LAMINATING RESINS
LEGEND
○ GASEOUS EMISSIONS
□ SOLID EMISSIONS
△ LIQUID EMISSIONS

FIGURE 10. PHENOLIC RESIN PRODUCTION

Polymerization (Resols)

1. Function - Phenol and formaldehyde react in an alkaline medium in a batch process. Phenol is charged to the agitated reactor through a weigh tank before the formaldehyde is similarly added, rinsing residual phenol out of the lines. Sodium hydroxide is added, and steam is supplied to the kettle jacket and to the internal coils to initiate the reaction. As the exothermic reaction begins, cooling water is supplied to the kettle to maintain temperature control. Additional cooling is accomplished by using a reflux condenser.

The degree of polymerization is monitored by withdrawing samples and testing them. The extent of reaction determines the molecular weight of the polymer and the physical properties of the product.

If the reaction is halted at the point at which the polymer is still water-soluble, the product may be used for bonding resins. If the reaction is allowed to progress to the point at which the polymer precipitates, the water may be removed, and organic solvent may be added to form a varnish. The polymerization reaction may be allowed to continue until the resin reaches a brittle stage, at which point it may be used for a thermosetting molding powder. Rapid cooling and neutralization with H_2SO_4 stop the reaction. The mixture is then distilled to purify the resin. If the resin application requires a low concentration of water, the resin is dehydrated, often under vacuum.

2. Input Materials - Formaldehyde, phenol and base are inputs to this process. Formaldehyde to phenol ratios are usually 1.5 to 1. Formaldehyde solutions may be 37 to 50 percent by weight and often contain 5 percent methanol which acts as a stabilizer. Solid paraformaldehyde is sometimes used.

The feed materials for a one-stage resin were reported by one source to be 1 to 2 parts calcium hydroxide to 100 parts phenol with a formaldehyde to phenol ratio of 1.1 to 1.5.

3 Operating Parameters - The pH of the polymerization reaction mixture is between 8 and 11. The kettle is heated to about 60°C to initiate the reaction. The temperature may then be held at 60 to 80°C or at a higher temperature. Reaction times for solid resins are from 1 to 5 hours depending on the temperature. The reaction is stopped by cooling to about 35°C. Pressure may range from 7 to 70 kPa (1 to 10 psi).

Kettle sizes vary from 7.6 to 38 m^3. Turbine agitators are adequate for production of resin solutions (viscosity $\sim$ 2 Pa·s [20 poise]), but close-fitting anchor-type agitators equipped with powerful motors are required for solid resin production (viscosity $\sim$ 30 Pa·s[300 poise]). Materials of construction were specified in one source of information as stainless steel or Monel.

4. Utilities - Steam and cooling water are required for temperature control. Power is required for agitation and for pumps. No quantitative data were found in the sources consulted for this study.

5. Waste Streams - A liquid waste stream results from distillation of the reaction mixture containing water, phenol, formaldehyde, and low molecular weight polymer. This waste stream requires careful treatment and disposal. Dehydration procedures may add to the waste-water stream. Carbon adsorption and liquid extraction are control methods in use for phenol recovery.

Fugitive gaseous emissions occur at the condenser, vacuum line, sample ports, and vents. Intermittent emissions occur at safety blow-off valves. These gaseous emissions contain phenol and formaldehyde.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02; Bakelite - General 3-01-018-05.

7. **References** -

(1) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(2) Florentine, Frank P. Phenolic. In: Modern Plastics Encyclopedia, Vol 51, No. 10A, Sidney Gross, ed. N.Y., McGraw-Hill, October 1974, p. 58.

(3) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(4) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 267- 71.

(5) Keutgen, W. A. Phenolic Resins. In: Kirk-Othmer Encyclopedia of Chemical Technology, Vol 15. Anthony Standen, ed. N.Y., Wiley, 1968, p. 176-208.

(6) Sittig, Marshall. Pollution Control in the Plastics and Rubber Industry. Park Ridge, N.J., Noyes Data Corp., 1975.

(7) Unit Processes in Organic Synthesis, 5th Ed. Philip H. Groggins, ed. N. Y., McGraw-Hill, 1958, p. 943-1035.

Product Preparation (Resols)

1. Function - There are generally three types of resol products prepared in this process. Water-soluble bonding resins, varnishes and laminating resins, and dry thermosetting molding powder. The production of dry product requires discharge of the resin from the reactor through a special quick-discharge valve to prevent it from becoming an insoluble, infusible solid. Cooling must be accomplished by spreading the material in thin layers because of the low thermal conductivity. Cooling devices include water- or air-cooled floors, trays in racks, and moving belts. After cooling, the solid is ground, screened, and packaged. Some of the solid resols require several water washing steps. This procedure necessitates drying the resin before it is packaged. The solid resin may be blended with fillers and additives before it is readied for marketing.

The water soluble bonding resins are discharged from the reactor to a filter. After filtration, the substance is packaged in drums or tanks.

The varnish and laminate resin solutions (non-water-soluble) are dissolved in a solvent, filtered, and then stored in drums or tanks for sale.

2. Input Materials - The resol formed in Process No. 19, solvents, fillers, and additives are feed materials to this process. Solvents in use include cellosolve acetate, butanol, ethanol, methyl ethyl ketone, and cyclohexanone.

3. Operating Parameters - Data were not found in the literature consulted for this study.

4. Utilities - Cooling water and/or air are required. Power for grinding is also necessary. No quantitative data were available in the sources consulted for this study.

5. Waste Streams - Screening procedures in preparing the dry, solid resin generate some solid waste. Grinding and packaging may emit particulates to the atmosphere. Filtration of the liquid resin products is another source of solid waste. Water washing of some resols produces a waste-water stream. No quantitative data were available in the sources consulted for this study.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02; Bakelite - General 3-01-018-05

7. References -

(1) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(2) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(3) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 267-71.

(4) Keutgen, W. A. Phenolic Resins. In: Kirk-Othmer Encyclopedia of Chemical Technology, Vol 15. Anthony Standen, ed. N.Y., Wiley, 1968, p. 176-208.

(5) Sittig, Marshall. Pollution Control in the Plastics and Rubber Industry. Park Ridge, N.J., Noyes Data Corp., 1975.

(6) Unit Processes in Organic Synthesis, 5th Ed. Philip H. Groggins, ed. N.Y., McGraw-Hill, 1958, p. 943-1035.

Polymerization (Novolaks)

1. Function - In this batch process formaldehyde and phenol are polymerized under acid conditions with a deficiency of formaldehyde to produce a thermoplastic product.

As in Process No. 19, phenol, acid, and formaldehyde are charged to a jacketed batch-reactor. An acid, frequently sulfuric or hydrochloric acid, is added and the temperature is raised to initiate the reaction. If strongly acid conditions are used, a vacuum reflux system must be employed for cooling; for some polymerizations atmospheric reflux is sufficient. Additional cooling is provided by circulating cooling water in the jacket and in the internal coils of the reactor.

When the reaction is completed, the resin is purified by distillation and dehydrated under vacuum.

2. Input Materials - Formaldehyde, phenol, and acid are inputs to this process. The ratio of formaldehyde to phenol is normally 0.75 to 0.90. Formaldehyde solutions of 37 to 50% by weight are used. These solutions often contain 5% methanol by weight. Solid paraformaldehyde is also used. One source listed feed materials for a novolak resin as 100 parts phenol, 0.5 parts concentrated H_2SO_4, and 69 parts of 37% formaldehyde. These quantities amount to 0.8 mole formaldehyde per mole of phenol. Another source of information reports that 0.835 Mg (1,840 lb) of phenol and 0.663 Mg (1,460 lb) of 40% formaldehyde are required per 0.9 Mg (one ton) resin produced.

3. Operating Parameters - The pH of the reaction mixture is usually 0.5 to 1.5. The kettle is heated to 60 to 85°C to initiate the reaction. A vacuum reflux system is used to maintain the reaction temperature to 85 to 90°C. Mildly acidic reactions are allowed to reflux at atmospheric conditions. Distillation temperatures are allowed to reach 120 to 150°C. Vacuum dehydration conditions are 160°C and 84 to 91 kPa (63.5 to 68.5 cm of Hg). Reaction times are 3 to 6 hours.

Kettle sizes range from 7.6 to 38 m^3; kettles are constructed of stainless steel or Monel. Turbine or anchor-type agitators are used.

4. Utilities - Steam and cooling water are required for temperature control. Power is required for agitation and for pumps. No quantitative data were found in the sources consulted for this study.

5. Waste Streams - Distillation and dehydration result in a liquid waste stream containing phenol, formaldehyde, acid, and low molecular weight polymer. This waste stream requires careful treatment and disposal. A caustic solution is used to clean the reactors. This caustic solution contributes to the wastewater stream for the plant. Fugitive gaseous emissions occur at the condenser, vacuum line, sample ports, and vents. Intermittent emissions occur at the safety blow-off valves. These gaseous emissions contain formaldehyde and phenol.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the plastics and Synthetic Materials Manfacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(2) Florentine, Frank P. Phenolic. In: Modern Plastics Encyclopedia, Vo. 51, No. 10A. Sidney Gross, ed. N.Y., McGraw-Hill, October 1974, p. 58.

(3) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(4) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 267-71.

(5) Keutgen, W. A. Phenolic Resins. In: Kirk-Othmer Encyclopedia of Chemical Technology, Vol 15. Anthony Standen, ed. N.Y., Wiley, 1968, p. 176-208.

(6) Sittig, Marshall. Polluton Control in the Plastics and Rubber Industry. Park Ridge, N.J., Noyes Data Corp., 1975.

Product Preparation (Novolaks)

1. Function - The novolak resin products are produced from the reactor product of Process 21. The molten polymer may be neutralized before it is further processed. In making a solid resin product the charge is dumped onto cooling surfaces in thin layers. Water- or air-cooled floors, trays in racks, and moving belts are used for rapid cooling. The solid resin is then ground and screened. Fillers, coloring agents, and hexamethylenetetramine may be blended with the resin before it is packaged. It may then be fused on hot rollers, ground and packaged as a finished product thermosetting resin. If a product is needed in solution (varnishes and laminating agents), solvent is added in the kettle. The solution is then packaged in drums or tanks.

2. Input Materials - The reactor product, solvent, fillers, hexamethylene tetramine, and other additives are input materials to this process. One source of information states that 10 to 15 parts hexamethylenetetramine per 100 parts novolak resin are blended with additives in a 50:50 ratio, that is 50 parts resin and hexamethylenetetramine to 50 parts additives. Solvents in use include cellosolve acetate, butanol, ethanol, methyl ethyl ketone, and cyclohexanone.

3. Operating Parameters - Data were unavailable in the literature consulted for this study.

4. Utilities - Cooling water and/or air are required. Power for grinding is also necessary. No quantitative data were available in the sources consulted for this study.

5. Waste Streams - Blending, screening, grinding, and packaging procedures may emit particulates to the atmosphere. No quantitative data were available in the sources consulted for this study.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(2) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(3) Jones, Robert W. and K. T. Chandv. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 267-71.

(4) Keutgen, W. A. Phenolic Resins. In: Kirk-Othmer Encyclopedia of Chemical Technology, Vol 15. Anthony Standen, ed. N.Y., Wiley, 1968, p. 176-208.

(5) Sittig, Marshall. Pollution Control in the Plastics and Rubber Industry. Park Ridge, N.J., Noyes Data Corp., 1975.

(6) Unit Processes in Organic Synthesis, 5th Ed. Philip H. Groggins, ed. N.Y., McGraw-Hill, 1958, p. 943-1035.

AMINO RESIN PRODUCTION PROCESSES

Amino resins are produced by the reaction of formaldehyde with nitrogen-containing compounds, the most important of which are urea and melamine. The chemistry is complex but basically involves two steps. Intermediate compounds are formed which subsequently condense to form polymer materials.

In commercial production the reaction is controlled so that only a small amount of polymerization takes place. The user completes the polymerization by the addition of acid and/or heat to form a thermosetting plastic.

Quantitative data concerning wastes from the individual processes in this operation were not available in the sources consulted for this study. Some waste stream data were available concerning the whole operation and are presented in Table 22.

Table 22. EMISSION DATA FOR AMINO RESIN PRODUCTION

	Urea-Formaldehyde Resins	Melamine-Formaldehyde Resins
Waste water flow	0.90 m^3/Mg of product (216 gallons/ton of product)	0.64 m /Mg of product (154 gallons/ton of product)
Formaldehyde	35 g/kg of product (70 lb/ton of product)	20 g/kg of product (40 lb/ton of product)
Urea	35 g/kg of product (70 lb/ton of product)	———
Melamine	———	20 g/kg of product (40 lb/ton of product)

Source: Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

Figure 11 is a diagram relating the three processes described herein: 23) Polymerization, 24) Alkylation, and 25) Product Preparation.

The processing methods presented here are the ones described in the literature consulted for this study. There appears to be variability in processing methods involved in making amino resins.

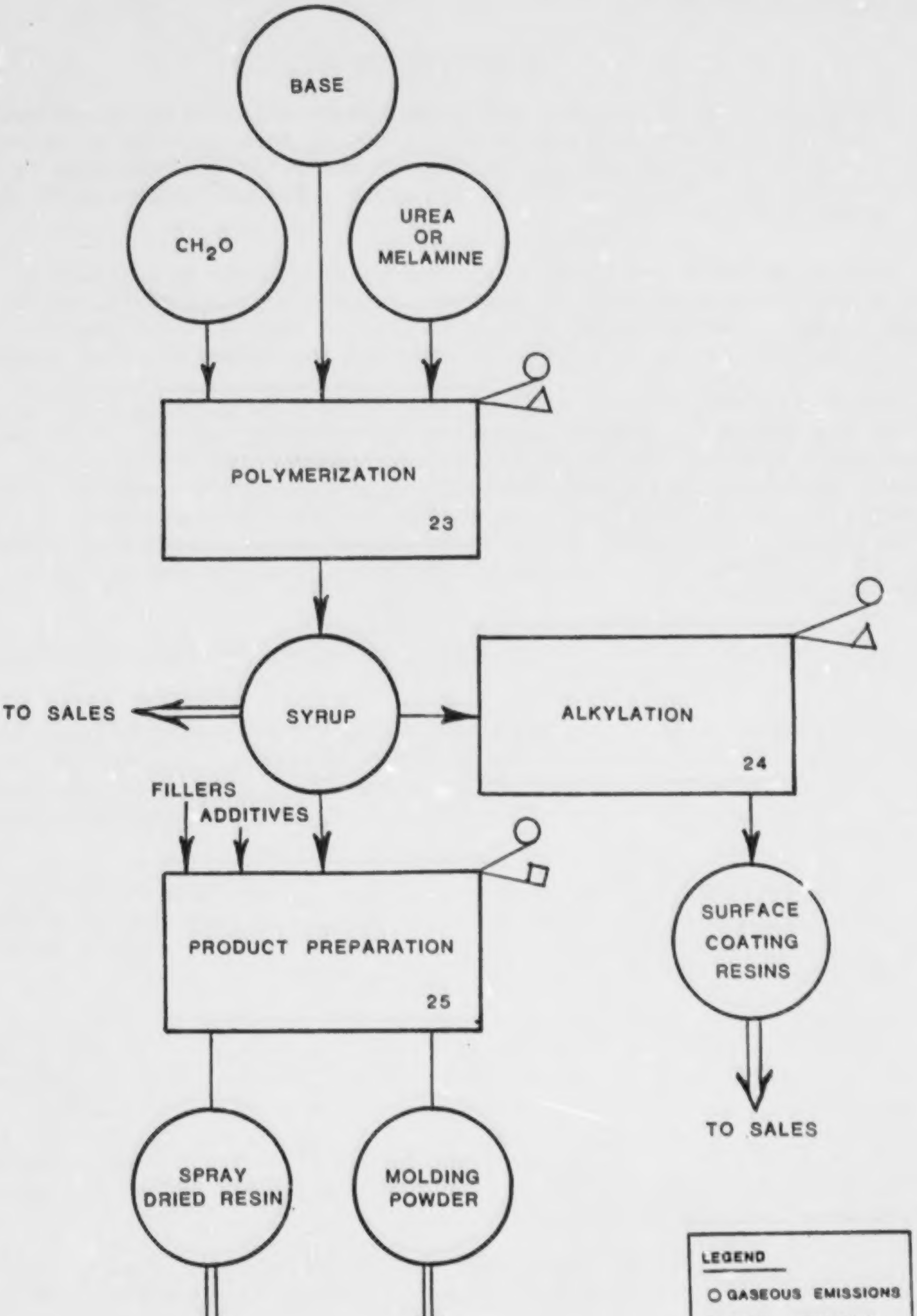

BASE
CH_2O
UREA OR MELAMINE
POLYMERIZATION
23
SYRUP
TO SALES
ALKYLATION
24
FILLERS
ADDITIVES
PRODUCT PREPARATION
25
SURFACE COATING RESINS
TO SALES
SPRAY DRIED RESIN
MOLDING POWDER
TO SALES
TO SALES
LEGEND
○ GASEOUS EMISSIONS
□ SOLID EMISSIONS
△ LIQUID EMISSIONS

FIGURE 11. AMINO RESIN PRODUCTION

Polymerization

1. Function - Urea or melamine and formaldehyde are allowed to condense under controlled pH and temperature conditions to form polymers of molecular weights suitable for specific applications. The batch-type reaction is generally stopped at a low molecular weight stage. Further condensation is done by the user.

Urea or melamine and formalin solutions are charged to a jacketed, stirred kettle equipped with a condenser, internal cooling coils, and a vacuum system. The equipment is very similar to that used for phenolic resin production and may, in fact, be used for both types of resin production.

The reaction mixture is adjusted to a neutral or slightly alkaline pH and the temperature is controlled during the reaction. Formation of the intermediate methylol compounds and further condensation of the intermediates are monitored by periodic sampling of the reactor contents. When viscosity measurements indicate the appropriate degree of polymerization, the temperature is lowered and the pH is raised to curtail further condensation. The condenser outlet is then transferred to a receiver to facilitate vacuum dehydration.

2. Input Materials - Urea, formaldehyde, melamine, and alkaline compounds are all inputs to this process.

Formaldehyde is generally used as a 30 to 40% aqueous solution. Methanol is present as a stabilizer in formalin solutions and must be removed for production of urea resins but may be tolerated in production of melamine resins. Formic acid must also be removed, as it catalyzes the polymerization reaction.

For a urea resin one source specifies that 1.7 Mg (3760 lb) of 40% formalin and 0.68 Mg (1500 lb) of urea are required per 0.9 Mg (one ton) of product. Molar ratios of formaldehyde to nitrogen compound cited in another source are 1.6 to 1.7:1 for urea and 2 to 3:1 for melamine.

3. Operating Parameters - In making a urea-formaldehyde resin the initial pH is adjusted to 7.0 to 7.8. The pH may be allowed to drop to 4 or 5 as the reaction continues. To stop the reaction, the pH is adjusted to slightly alkaline. Refluxing occurs at atmospheric pressure (100°C) and subsequently at a cooler temperature under vacuum (40 to 70°C). Reaction times for the urea-formaldehyde resin are given in one source as 2 hours under atmospheric reflux plus 5 hours under vacuum reflux with a total cycle time for polymerization and drying of 10 hours.

For melamine resin production the initial pH is adjusted to 9, and the reaction temperature is held at 80°C until the methylolation has taken place.

Kettle capacity may be 7.6 to 38 m^3. Construction materials are stainless steel or monel.

4. Utilities - Quantitative information was not available in the sources cited for this study. Power is required for agitation; steam and cooling water are also required.

5. Waste Streams - The water removed under vacuum forms a liquid waste stream containing formaldehyde and urea or melamine. Fugitive gaseous emissions may occur at relief valves. These gaseous emissions contain formaldehyde and urea or melamine along with intermediate compounds. The kettles are cleaned between batches by washing with caustic solution. This solution becomes part of the waste water associated with the plant.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Cordier, E. C. Amino. In: Modern Plastics Encyclopedia. Vol 51, No. 10A. Sidney Gross, ed. N.Y., McGraw-Hill, October 1974, p. 25

(2) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(3) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(4) Sittig, Marshall. Pollution Control in the Plastics and Rubber Industry. Park Ridge, N.J., Noyes Data Corp., 1975.

(5) Unit Processes in Organic Synthesis, 5th Ed. Philip H. Groggins, ed. N.Y., McGraw-Hill, 1958, p. 943-1035.

(6) Vale, C. P. Aminoplastics. New York, Interscience Publishers, Inc., 1950.

(7) Widmer, Gustave. Amino Resins. In: Encyclopedia of Polymer Science and Tehcnology, Vol 2. H.F. Mark, ed. N.Y., Wiley, 1965, p. 1-95.

Alkylation

1. Function - Amino resin condensation products are generally insoluble in common organic solvents and incompatible with other surface coating resins such as alkyds. Solubility in organics is increased by alkylating the condensation products from Process No. 23. Alkylation is accomplished by reaction with an alcohol. The alcohol and water are removed by distillation.

2. Input Materials - Condensation products from Process No. 23, formaldehyde, and an alcohol are feed materials to this process. Common alcohols in use are methanol, butanol, and octanol.

3. Operating Parameters - One source of information indicates that a close-fitting anchor-type agitator is required, as the viscosity of the reactor contents reach 30 Pa•S (300 poise). Other operating parameters were not found in the sources consulted for this study.

4. Utilities - Information was unavailable in the sources consulted for this study.

5. Waste Streams - The alcohol and water removed by distillation probably forms a liquid waste stream. There was no indication of its final disposition in the literature consulted for this study. Fugitive gaseous emissions at the condenser, valves, and fittings probably occur. If there is a relief vent, intermittent emissions may occur there. These gaseous emissions will contain formaldehyde and alcohol vapors.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Cordier, E. C. Amino. In: Modern Plastics Encyclopedia, Vol 51, No. 10A, Sidney Gross, ed. N.Y., McGraw-Hill, October 1974, p. 25.

(2) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(3) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(4) Rodriguez, Ferdinand. Principles of Polymer Systems. N.Y., McGraw-Hill, 1970.

(5) Sittig, Marshall. Pollution Control in the Plastics and Rubber Industry. Park Ridge, N.J., Noyes Data Corp., 1975.

(6) Unit Processes in Organic Synthesis, 5th Ed. Philip H. Groggins, ed. N.Y., McGraw-Hill, 1958, p. 943-1035.

Product Preparation

1. Function - The condensation products from Processes No. 23 and 24 may be marketed in three forms: a viscous resin syrup, a spray-dried resin, or a molding powder.

The reactor contents may be used directly or stored for shipment as a water or alcohol soluble syrup which is fully polymerized by the user with the application of acid and/or heat.

If the resin must be stored before its use, it may be provided in dry form to be dissolved in water or alcohol when it is needed. This is accomplished by spray drying the syrup of condensation products. Spray-dried resin is also blended into molding powders to achieve the proper flow characteristics. Molding powders are generally made by impregnating filler materials with amino resin. The filler and resin are mixed, dried, pulverized, and densified to produce a molding compound. A kneading-type mixer (Banbury or Werner-Pfleiderer) is used to mix the resin with the filler and a small amount of mold release agent (lubricant). This mechanical mixing breaks the filler into individual fibers and impregnates them with resin. Drying is generally accomplished in a continuous-drum or continuous-screen dryer. An impact pulverizing machine such as a hammer mill is first used to pulverize the dried resin material. Further pulverizing is accomplished in a ball mill which also serves to densify the resin. Additives and pigments may be mixed with the material in the ball mill to produce a finished molding powder.

An alternative method of preparing a molding powder involves mixing and drying under vacuum with hot air circulation within the kneading-type mixer. The mixture is screened before it is passed through an impact mill where a dense molding compound is produced. The large screenings are recycled to the mixer. This method produces molding powders of inferior quality compared with those produced by the first method.

2. Input Materials - The product of the condensation reaction is the major feedstream to this process. Fillers such as alpha cellulose, wood flour, and asbestos; pigments; mold release agents (lubricants) and other additives are also used. Ethanol may be used as a solvent. Air is needed for spray drying.

3. Operating Parameters - The mixer temperature range is 50 to 80°C. Drum dryer air temperatures are 70 to 120°C. Air temperatures are 20 to 30°C lower on the conveying screen dryer. Air temperatures for spray drying urea resins are cited in one source as 230 to 260°C (450 to 500°F) at the inlet and 82 to 88°C and (180 to 190°F) at the outlet. Pressures encountered in Banbury mixers are generally 0.10 to 0.14 MPa (15 to 20 psi).

4. Utilities - Power requirements for Werner-Pfleiderer mixers range from 33 to 390 kW/m (0.67 to 2.0 hp/gal) capacity. A No. 11 Banbury mixer operating at 20 rpm and processing 0.25 m^3/10 min (9 ft^3/10 min) requires 190 kW (250 hp), while one operating at 40 rpm processing 0.25 m^3/5 min (9 ft^3/5 min) requires 370 kW (500 hp).

5. Waste Streams - Spray-drying operations may produce particulate emissions. Cyclones and bag filters are often used as collection devices.

Belt driers, continuous-drum dryers and continuous screen dryers produce water-laden air which is vented to the atmosphere. This gaseous waste stream contains organic compounds and particulates.

Pulverizing and packaging operations are a potential source of particulate emissions.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Chemical Engineers' Handbook, 4th Ed. Robert H. Perry, ed. N.Y., McGraw-Hill, 1963.

(2) Cordier, E. C. Amino. In: Modern Plastics Encyclopedia, Vol 51, No. 10A, Sidney Gross, ed. N.Y., McGraw-Hill, October 1974, p. 25.

(3) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(4) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(5) Rodriguez, Ferdinand. Principles of Polymer Systems. N.Y., McGraw-Hill, 1970.

(6) Sittig, Marshall. Pollution Control in the Plastics and Rubber Industry. Park Ridge, N.J., Noyes Data Corp., 1975.

(7) Unit Processes in Organic Synthesis, 5th Ed. Philip H. Groggins, ed. N.Y., McGraw-Hill, 1958, p. 943-1035.

(8) Vale, C. P. Aminoplastics, New York, Interscience Publishers, 1950.

POLYCARBONATE PRODUCTION PROCESSES

Polycarbonates are linear thermoplastic polyesters of carbonic acid. The only commercially important polycarbonate is formed by the reaction of bisphenol-A with phosgene in the presence of pyridine. The commercial process described in this operation is the one employed by the General Electric Company. It is the only commercial process for which information was found in the literature consulted for this study. Reference has been made to the fact that Mobay Chemical Company has a process based on diphenyl carbonate instead of phosgene. No information concerning the process was found in the literature consulted for this study, however.

Quantitative data on utilities requirements were available for the entire operation and are presented in Table 23.

Table 23. UTILITY REQUIREMENTS FOR POLYCARBONATE MANUFACTURE[a]

cooling water	2 m^3/min	(500 gal/min)
steam, 1.4 MPa (200 psig)	8.6 Mg/hr	(19,000 lb/hr)
electricity	810 kW	
refrigeration	19.8 GJ	(65 tons)

[a] 9 Mg/yr (20,000 lb/yr) capacity

Source: Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

Quantitative emissions data were generally scarce in the sources consulted for this study. The use of phosgene and pyridine indicates the potential for toxic emissions problems.

Figure 12 is a flow sheet which illustrates the five processes included in this operation: 26) Polymerization, 27) Washing, 28) Precipitation, 29) Drying, and 30) Product Preparation.

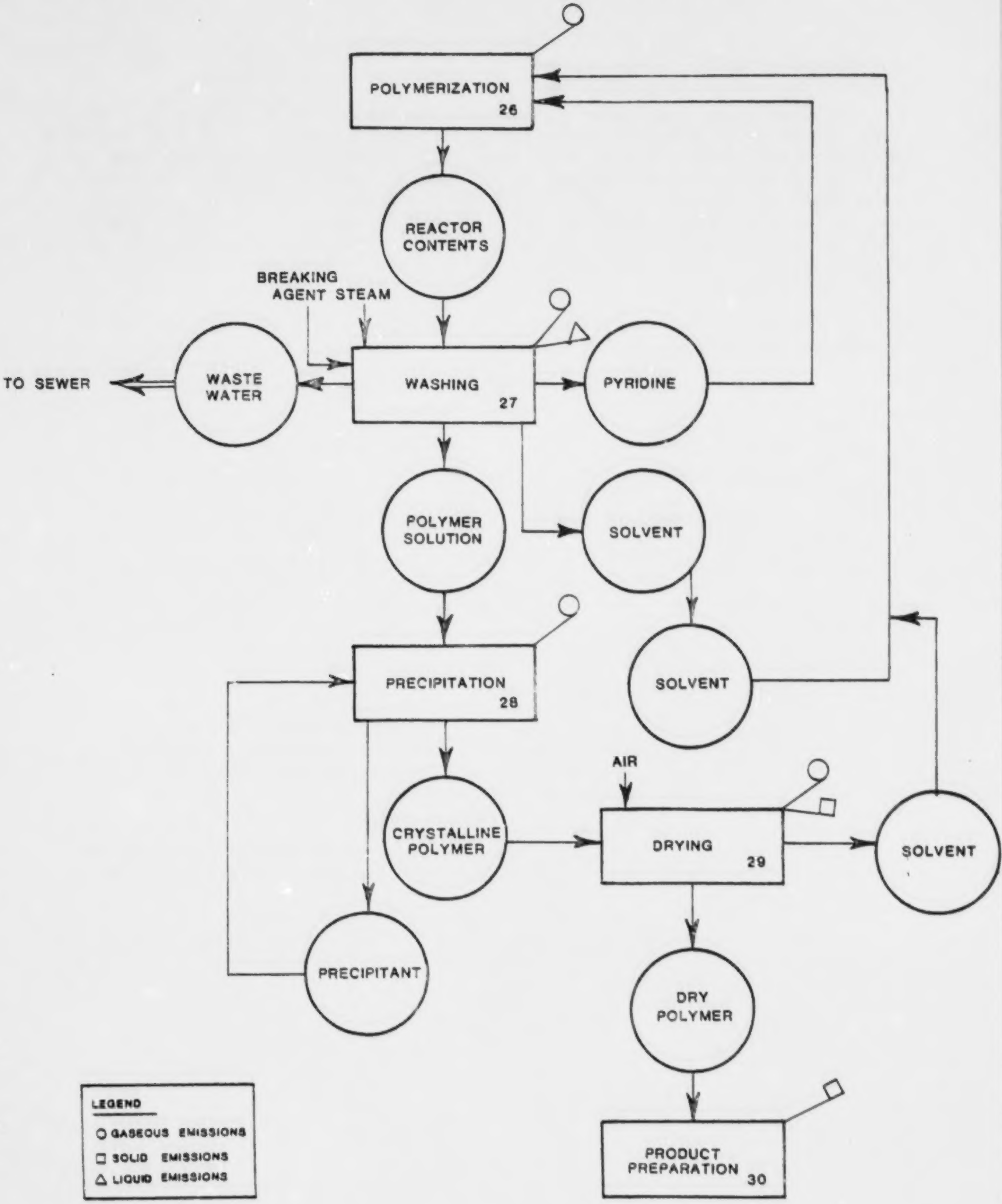

POLYMERIZATION
26
REACTOR CONTENTS
BREAKING AGENT STEAM
TO SEWER
WASTE WATER
WASHING
27
PYRIDINE
POLYMER SOLUTION
SOLVENT
SOLVENT
PRECIPITATION
28
CRYSTALLINE POLYMER
AIR
DRYING
29
SOLVENT
PRECIPITANT
DRY POLYMER
PRODUCT PREPARATION
30
LEGEND
○ GASEOUS EMISSIONS
□ SOLID EMISSIONS
△ LIQUID EMISSIONS

FIGURE 12. POLYCARBONATE PRODUCTION

Polymerization

1. Function - Bisphenol-A, pyridine, and a chlorinated hydrocarbon solvent are charged to an agitated, jacketed reaction vessel. Phosgene in the gaseous state is bubbled through the reactor contents.

Temperature is carefully controlled by circulating water through the reactor jacket. The reactor contents containing polymerized product, unreacted pyridine, and pyridine hydrochloride are treated by washing (Process No. 27) when the reaction is complete.

2. Input Materials - Input materials are phosgene vapor, bisphenol-A, pyridine, and a solvent such as methylene chloride or chlorobenzene. It is reported that an excess of pyridine may be used to provide the basic medium necessary for the reaction. The reactants must be free of monofunctional alcohols or phenols which act as chain terminators. Pyridine and solvent are recycled so that make-up requirements are thought to be low. Polycarbonates require 0.08 Mg (1780 lb) Bisphenol-A and 36 kg (810 lb) of phosgene.

3. Operating Parameters - The important factors affecting the polymerization reaction include residence time, temperature, purity of reactants, and proportions of reactants. Reaction temperature for a typical process is below 40°C (104°F). The residence time is 1 to 3 hours.

4. Utilities - See Table 23.

5. Waste Streams - Fugitive gaseous emissions are likely to occur at valves and fittings in this process. These fugitive emissions may contain phosgene and pyridine which have offensive odors and toxic properties.

6. EPA Source Classification Code - Polyprod. General 30-1-018-02

7. References -

(1) Bottenbruch, L. Polycarbonates. In: Encyclopedia of Polymer Science & Technology, Vol 10. H. F. Mark, ed. Y.Y., Wiley, 1969, p. 710-64.

(2) Chopey, N. P. Making Polycarbonates: A First Look. Chemical Engineering, 1953 (14 Nov.), 174-77.

(3) Environmental Protection Agency, Effluent Guidelines Division. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Polymers Segment of the Plastics and Synthetic Materials Manufacutring Point Source Category. EPA 440/1-75/-36-b. Washington, D.C., Jan. 1975.

(4) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(5) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 292.

(6) Polycarbonates--General Electric Company. Hydrocarbon Processing, 44:262, November 1965.

Washing

1. Function - The reactor contents from Process No. 26 are fed to wash tanks for removal of residual pyridine. Washing is done with hydrochloric acid and water. The excess pyridine is thus converted to pyridine hydrochloride. The aqueous phase is removed by decantation. Polymer is recovered from the solvent phase by precipitation (Process No. 28).

Pyridine is recovered from the aqueous phase. Sodium hydroxide is combined with the pyridine hydrochloride solution to form sodium chloride, then solvent is removed by steam stripping. An azeotropic distillation column separates sodium chloride as bottoms and a pyridine-water azeotrope as an overhead stream. The azeotrope is dehydrated by a proprietary method involving the addition of a breaking agent and distillation. The overhead pyridine stream is recycled, while the bottoms are treated for recovery of breaking agent. The disposition of the water is not indicated in the sources consulted for this study.

2. Input Materials - Polymerization reactor contents from Process No. 16, sodium hydroxide, and an undisclosed breaking agent are feed streams. Steam is required for removal of solvent by steam stripping.

3. Operating Parameters - Information was not available in the sources consulted for this study.

4. Utilities - See Table 23.

5. Waste Streams - The washing process is the major source of waste water for this operation. The waste water will probably be alkaline, and its major constituent is sodium chloride. Sodium chloride produced in this manner amounts to 0.69 Mg (1520 lb) per 0.90 Mg (one ton) of product. Fugitive emissions of pyridine and solvent are expected from the stripping and distillation columns. The method of disposition of the water removed from the pyridine is not mentioned. It may be sent to disposal, or some of the water may be recovered. It is probable that some waste water contaminated with pyridine will result.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Bottenbruch, L. Polycarbonates. In: Encyclopedia of Polymer Science & Technology, Vol 10. H. F. Mark, ed. N.Y., Wiley, 1969, p. 710-64.

(2) Chopey, N. P. Making polycarbonates: A First Look. Chemical Engineering, 1953 (14 Nov.), 174-77.

(3) Environmental Protection Agency. Effluent Guidelines Division. Development Document for Effluent Limitations Guidelines and New

Source Performance Standards for the Synthetic Polymers Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-75/036-b. Washington, D.C., Jan. 1975.

(4) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(5) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Reigel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 292.

(6) Polycarbonates--General Electric Company. Hydrocarbon Processing, 44:262, November 1965.

Precipitation

1. Function - The polymer-solvent stream from Process No. 27 is treated with an organic compound such as an aliphatic hydrocarbon to effect precipitation of the polymer. The polycarbonate precipitates and is separated by filtration; a rotary filter is indicated as a possible equipment choice. The powder is transferred to a drying process, while the solvent and precipitant are recovered in a distillation column.

2. Input Materials - The polymer solution and the precipitant are feed streams to this process.

3. Operating Parameters - Data were not available in the sources consulted for this study.

4. Utilities - See Table 23.

5. Waste Streams - Fugitive gaseous emissions of hydrocarbon compounds probably occur as a result of the distillation employed for solvent and precipitant recovery.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Bottenbruch, L. Polycarbonates. In: Encyclopedia of Polymer Science & Technology, Vol 10. H. F. Mark, ed. N.Y., Wiley, 1969, p. 710-64.

(2) Chopey, N. P. Making Polycarbonates: A First Look. Chemical Engineering, 1953 (14 Nov.), 174-77.

(3) Environmental Protection Agency, Effluent Guidelines Division. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Polymers Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-75/036-b. Washington, D.C., Jan. 1975.

(4) Hedley, W. N., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(5) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 292.

(6) Polycarbonates--General Electric Company. Hydrocarbon Processing, 44:262, November 1965.

Drying

1. Function - The polymer is dried by direct contact with hot air. The exact type of dryer is not readily evident from the information consulted for this study. Dust collectors are auxiliary pieces of equipment necessary to prevent excessive product losses.

2. Input Materials - Hot air and polymer are input materials to this process. The flow rate of air required to evaporate 0.5 kg (1 lb) of water is 0.23 to 0.28 m^3/min (8 to 10 ft^3/min). The air flow in large polymer dryers may be 570 to 850 m^3/min (20,000 to 30,000 ft^3/min).

3. Operating Parameters - None were available in the sources consulted for this study.

4. Utilities - See Table 23.

5. Waste Streams - Dusting is a problem in drying operations. If cyclones alone are used for control, a significant loss of product may occur. Assuming 99 percent collection efficiency, a plant with an annual capacity of 23 Gg (50 million lb) will produce particulate emissions of 230 Mg (500,000 lb) per year.

Although a solvent recovery step is indicated in the literature, it is possible that air exhausted from the drying operation will contain traces of solvent.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Bottenbruch, L. Polycarbonates. In: Encyclopedia of Polymer Science & Technology, Vol 10. H. F. Mark, ed. N.Y., Wiley, 1969, p. 710-64.

(2) Chopey, N. P. Making Polycarbonates: A First Look. Chemical Engineering, 1953 (14 Nov.), 174-77.

(3) Environmental Protection Agency, Effluent Guidelines Division. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Polymers Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-75/036-b. Washington, D.C., Jan. 1975.

(4) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(5) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 292.

(6) Oringer, Kenneth. Current Practice in Polymer-Recovery Operations. Chemical Engineering, 79: 29-106, 20 March 1972.

PRODUCT PREPARATION

1. Function - The dried polymer material is extruded and pelletized for use as a molding powder. Single-stage screw extruders are commonly used pieces of equipment. It is likely that typical pelletizing machines are used.

2. Input Materials - Dried polymer powder.

3. Operating Parameters - None were available in the sources consulted for this study.

4. Utilities - See Table 23.

5. Waste Streams - Pelletizing operations are a potential source of particulate emissions.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Bottenbruch, L. Polycarbonates. In: Encyclopedia of Polymer Science & Technology, Vol 10. H. F. Mark, ed. N.Y., Wiley, 1969, p. 710-64.

(2) Chopey, N. P. Making Polycarbonates: A First Look. Chemical Engineering, 1953 (14 Nov.), 174-77.

(3) Environmental Protection Agency, Effluent Guidelines Division. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Polymers Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-75/036-b. Washington, D. C., Jan. 1975.

(4) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

EPOXY RESIN PRODUCTION PROCESSES

Epoxy resins, characterized by the presence of epoxy groups within the molecule, are intermediate, thermoplastic materials which must be cured by the addition of reactive substances to form thermosetting materials. Curing agents include such materials as amines; polyamides; acids; acid anhydrides; and phenolic, urea, or melamine resins. The choice of curing agent is dictated by the specific end use of the resin, as the curing agents impart different properties to the final product.

Although epoxy resins may be obtained by condensation of epichlorohydrin with a number of polyphenols or polyacohols, more than 90 percent of the commercial production is of the resin formed by the reaction of epichlorohydrin with Bisphenol-A. This treatment is therefore limited to the discussion of the production of those specific resins.

Utilities are available on a weight of product basis for an unspecified method of production. Since they include requirements for the entire operation, these utility requirements are presented here in Table 24.

Table 24. UTILITY REQUIREMENTS FOR EPOXY RESIN PRODUCTION[a]

cooling water	5.3m^3/min(1400 gal/min)
steam (50 psig)	900kg/hr(2000 lb/hr)
(150 psig)	9.5Mg/hr(21,000 lb/hr)
power	125 kWh
process water	0.545m^3/min(144 gal/min)

[a] 9Mg/hr (20,000 lb/hr) capacity

Source: Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA 406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

A waste water loading of 2.5 to 5.1m^3/Mg has been reported for epoxy resin manufacture. The raw waste load from the entire operation is reported as follows: BOD_5, 57 to 82 kg/Mg; COD, 30 to 127 kg/Mg; suspended solids, 5 to 24 kg/Mg.

The processing methods presented are meant to represent typical operations. There are, undoubtedly, other ways to make epoxy resin products. Figure 13 is a schematic representation of the processes presented in this treatment.

The processes included in this operation are: 31) Polymerization (one step), 32) Polymerization (two steps), 33) Washing, and 34) Polymer Recovery.

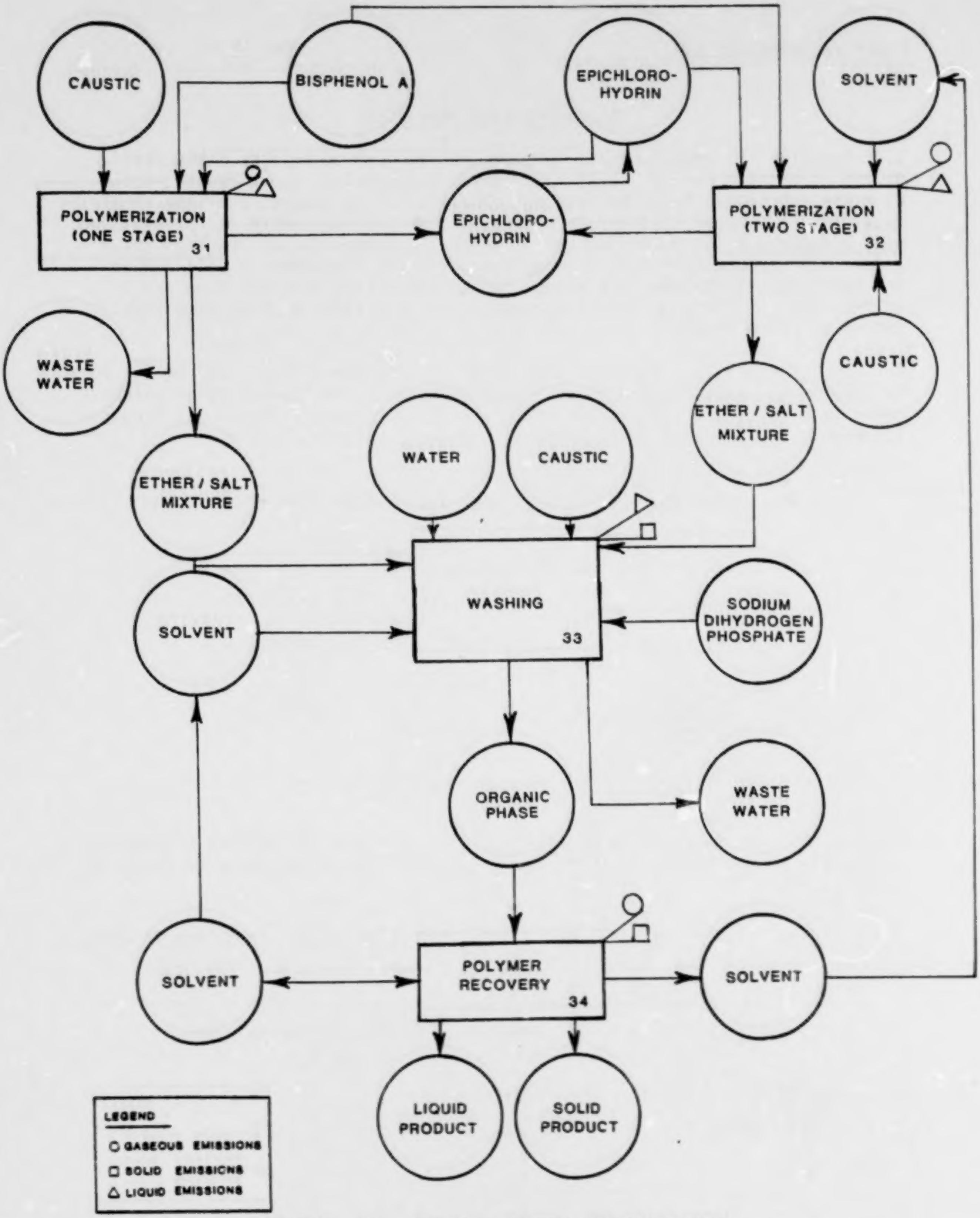

CAUSTIC
BISPHENOL A
EPICHLORO-HYDRIN
SOLVENT
POLYMERIZATION (ONE STAGE) 31
EPICHLORO-HYDRIN
POLYMERIZATION (TWO STAGE) 32
WASTE WATER
CAUSTIC
ETHER / SALT MIXTURE
WATER
CAUSTIC
ETHER / SALT MIXTURE
WASHING 33
SOLVENT
SODIUM DIHYDROGEN PHOSPHATE
ORGANIC PHASE
WASTE WATER
SOLVENT
POLYMER RECOVERY 34
SOLVENT
LIQUID PRODUCT
SOLID PRODUCT
LEGEND
○ GASEOUS EMISSIONS
□ SOLID EMISSIONS
△ LIQUID EMISSIONS

FIGURE 13. EPOXY RESIN PRODUCTION

Polymerization (One Step)

1. Function - A one-step batch process may be used to produce either solid or liquid product resins. Epichlorohydrin, Bisphenol-A, and a caustic solution are introduced into the reactor. The reactor is generally of the kettle type, fitted with an agitator, a heater, and a condenser which may be equipped with a separator for decanting reflux water. The epoxidation reaction takes place under atmospheric reflux conditions with the formation of salt. When the reaction is complete, the aqueous phase containing salt and some caustic is decanted. Epichlorohydrin is removed by distillation at both atmospheric and vacuum conditions.

2. Input Materials - The molecular weight of the epoxy resins may be varied by varying the epichlorohydrin to Bisphenol-A ratio. A low molecular weight resin requires a 10:1 mole ratio as indicated in Table 25, describing feed requirements for an epoxy resin production process patented by Shell

Table 25. INPUT MATERIALS FOR A SHELL EPOXY RESIN PRODUCTION PROCESS

Bisphenol-A	5130 parts (22.5 moles)
Epichlorohydrin	20,812 parts (225 moles)
Water	104 parts
Solid NaOH	1880 parts

The use of lower mole ratios result in higher molecular weight resin products. An example of materials necessary for the production of this type of resin is given in Table 26.

Table 26. INPUT MATERIALS FOR A ONE-STAGE EPOXY RESIN PRODUCTION PROCESS

Input Material	Volume (g/Kg Product)	Volume (lb/ton Product)
Bisphenol-A	670.5	1341
Epichlorohydrin	556	1112
NaOH	240	480

3. Operating Parameters - It appears that operating parameters may vary considerably from process to process. Temperature encountered are generally less than 200°C, however. The accounts of the Shell process specified reaction temperatures of 90 to 100°C. One of the unidentified one-step processes utilizes a reflux temperature of 77°C (171°F).

Distillation conditions cited in a description of the Shell process are 100°C at atmospheric conditions and 160°C at 133 Pa (1 mm/Hg).

4. Utilities - See Table 24.

5. Waste Streams - The aqueous phase decanted or separated from the reactor is a caustic liquid waste stream containing sodium salts. Refluxing during the reaction and distillation of the epichlorohydrin are potential sources of fugitive gaseous emissions. If steam ejectors are used for removal of epichlorohydrin, a fouled condensate results.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Bannerman, D. G., and E. E. Magat. Polyamides & Polyesters. In: Polymer Processes, Vol X. Calvin E. Schildknect, ed. N.Y., Interscience Publishers, 1956, p. 235-94.

(2) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(3) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(4) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 292.

(5) Potter, W. G. Epoxide Resins. London, Iliffe Books, 1970.

(6) Sittig, Marshall. Pollution Control in the Plastics and Rubber Industry. Park Ridge, N.H., Noyes Data Corp., 1975.

(7) Unit Processes in Organic Synthesis, 5th Ed. Philip H. Groggins, ed. N.Y., McGraw-Hill, 1958, p. 943-1035.

Polymerization (Two Steps)

1. Function - The two step process, used in an effort to minimize the molecular weight of the product, is suitable for producing liquid products and may be batch or continuous. An excess of epichlorohydrin is introduced with Bisphenol-A into the reactor with an unspecified catalyst. After a suitable reaction time has elapsed, the epichlorohydrin is removed by distillation for recycle. A solvent and caustic are then added to effect the epoxidation with the resulting formation of sodium chloride.

2. Input Materials - Input Materials for a two-step system are listed below in Table 27.

Table 27. INPUT MATERIALS FOR A TWO-STEP EPOXY RESIN POLYMERIZATION

Input Material	Volume (g/kg Product)
Bisphenol-A	690.4
Epichlorohydrin	512.7
50% NaOH Solution	443.4

Solvent quantities are not indicated; the solvent is usually a ketone such as methyl isobutyl ketone (MIBK).

3. Operating Parameters - Data were not available in the sources consulted for this study.

4. Utilities - See Table 24.

5. Waste Streams - The use of steam ejectors for vacuum removal of epichlorohydrin is indicated. This results in losses of epichlorohydrin in a fouled condensate. No accounts of methods of treatment or disposition of this waste stream were available in the literature consulted.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(2) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(3) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 292.

(4) Potter, W. G. Epoxide Resins. London, Iliffe Books, 1970.

(5) Sittig, Marshall. Pollution Control in the Plastics and Rubber Industry. Park Ridge, N.J., Noyes Data Corp., 1975.

Washing

1. Function - The epoxy polmer is washed with several reagents. The procedure most generally described in the literature consists of extraction of the ether and salt mixture with a solvent. The solvent is already present if the two-stage process described in Process No. 32 is used. The aqueous phase is discarded. The organic phase containing the epoxy is washed (often in the reactor vessel) with water followed by sodium hydroxide to remove the chlorine residue. Washing with sodium dihydrogen phosphate neutralizes the residual caustic.

2. Input Materials - 2218 g of wash water are required per kg of product according to one source of information. Another reference describing the process covered by a Shell patent prescribes a weight of MIBK equal to the weight of the reactor contents and three times that weight in water requirements. The sodium hydroxide solution used is an equal weight of 5% solution. The NaH_2PO_4 is a half-weight quantity of 2% solution.

3. Operating Parameters - The description of the process patented by Shell indicates a temperature of 25°C and agitation for two hours for the MIBK extraction. Washing with sodium hydroxide occurs at 80°C with an agitation time of one hour. The NaH_2PO_4 wash is performed at 25°C.

4. Utilities - See Table 24.

5. Waste Streams - The washing procedures generate a large volume of waste water. No indication of methods of treatment or disposition was evident in the literature consulted.

A solid waste stream is formed in the reactor bottoms. This solid waste consists of 41 kg (90 lb) MIBK, 312 kg (688 lb) NaCl, 15.2 kg (33.4 lb) Na_2HPO_4, and 13.4 kg (29.5 lb) epichlorohydrin-methanol by-product per ton of resin produced.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Bannerman, D. G., and E. E. Magat. Polyamides & Polyesters. In: Polymer Processes, Vol X. Calvin E. Schildknecht, ed. N.Y., Interscience Publishers, 1956, p. 235-94.

(2) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(3) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(4) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 292.

(5) Potter, W. G. Epoxide Resins. London, Iliffe Books, 1970.

(6) Sittig, Marshall. Pollution Control in the Plastics and Rubber Industry. Park Ridge, N.H., Noyes Data Corp., 1975.

(7) Unit Processes in Organic Synthesis, 5th Ed. Philip H. Groggins, ed. N. Y., McGraw-Hill, 1958, p. 943-1035.

Polymer Recovery

1. Function - In this process the polymer is isolated, and the final product is prepared. The organic solvent is removed from the resin by distillation under atmospheric and vacuum conditions for recycle.

The isolated resin may be stored in the liquid form for shipment to sales if its molecular weight is low enough. If it is a higher molecular weight resin, it may be solidified by cooling and ground to form a solid resin product. Alternatively, the liquid or solid resin may be dissolved in an organic solvent.

Various types of additives may be introduced to the resin to modify its properties for different end uses.

2. Input Materials - The organic phase from the washing operations and a solvent are feeds to this process.

Additives include diluents (aromatic hydrocarbons, dibutyl phthalate, pine oil, vinylcyclohex-3-ene dioxide, n-butyl glycidyl ether, phenyl glycidyl ether, p-tolyl glycidyl ether, glycidyl esters of tertiary carboxylic acids, tetramethylene diglycidyl ether); fillers (marble flour, chalk powder, silica flour, mica flour, slate powder, zircon flour, sand, vermiculite, phenolic microballoons, aluminum powder, asbestos fibre, chopped glass fibre, metal oxides, graphite, calcium carbonate); resinous modifiers (coal tar pitch, petroleum derived bitumens, furfural resins, unsaturated polyesters, PVC, teflon, silicone resins); and flexibilizers (glycidyl fatty acid esters).

3. Operating Parameters - Methyl isobutyl ketone is distilled at 160°C at atmospheric pressure and then at 133 Pa (1 mm Hg) at the same temperature. The resins generally have melting temperatures between 70° and 150°C.

4. Utilities - See Table 24.

5. Waste Streams - Distillation generally results in fugitive gaseous emissions of volatile solvent vapors. Grinding and packaging operations are potential sources of particulate emissions.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Bannerman, D. G., and E. E. Magat. Polyamides & Polyesters. In: Polymer Processes, Vol X. Calvin E. Schildknecht, ed. N.Y., Interscience Publishers, 1956, p. 235-94.

(2) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.). Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-73-010-a. Washington, D. C., 1974.

(3) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(4) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed James A. Kent, Ed. N.Y., Van Nostrand Reinhold, 1974, p. 292.

(5) Potter, W. G. Epoxide Resins. London, Iliffe Books, 1970.

(6) Sittig, Marshall. Pollution Control in the Plastics and Rubber Industry. Park Ridge, N.J., Noyes Data Corp., 1975.

(7) Unit Processes in Organic Synthesis, 5th Ed., Philip H. Groggins, ed. N.Y., McGraw-Hill, 1958, p. 943-1035.

UNSATURATED POLYESTER RESIN PRODUCTION PROCESSES

This operation concerns the manufacture of what are considered polyester resins in the plastics and resins industry. The definition is narrower than the strict chemical definition. Polyester resins are mixtures of unsaturated polyester resin and vinyl monomers which crosslink to form thermosetting plastics in the presence of curing agents. Curing agents include peroxides such as benzoyl peroxide, methyl ethyl ketone peroxide, di-t-butyl peroxide, and dicumyl peroxide. Curing is done at the fabrication point and may require heat as well as a curing agent.

Quantitative waste stream data were largely unavailable in the sources consulted for this study. Waste water loading for polyester resin manufacture was reported to be 0 to 167 m^3/Mg with a BOD_5 of 0 to 10 kg/Mg and a COD of 1 to 30 kg/Mg. Qualitative indications of the possible sources of emissions are given in the process descriptions. Utility data were found for the entire operation and are included in Table 28.

Table 28. UTILITY REQUIREMENTS FOR UNSATURATED POLYESTER RESIN PRODUCTION[a]

cooling water	1060 m^3 (280,000 gal)
electricity	740 kWh
steam	3.3 Mg (7200 lb)
natural gas	230 m^3 (8600 scf)

[a] Basis 13.4 Mg (29,600 lb)/12 hour. Batch-type solvent polymerization.

Source: Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

Figure 14 is a process flow sheet illustrating the processing sequence involved in this operation. Two process descriptions are included: 35) Polymerization and 36) Mixing.

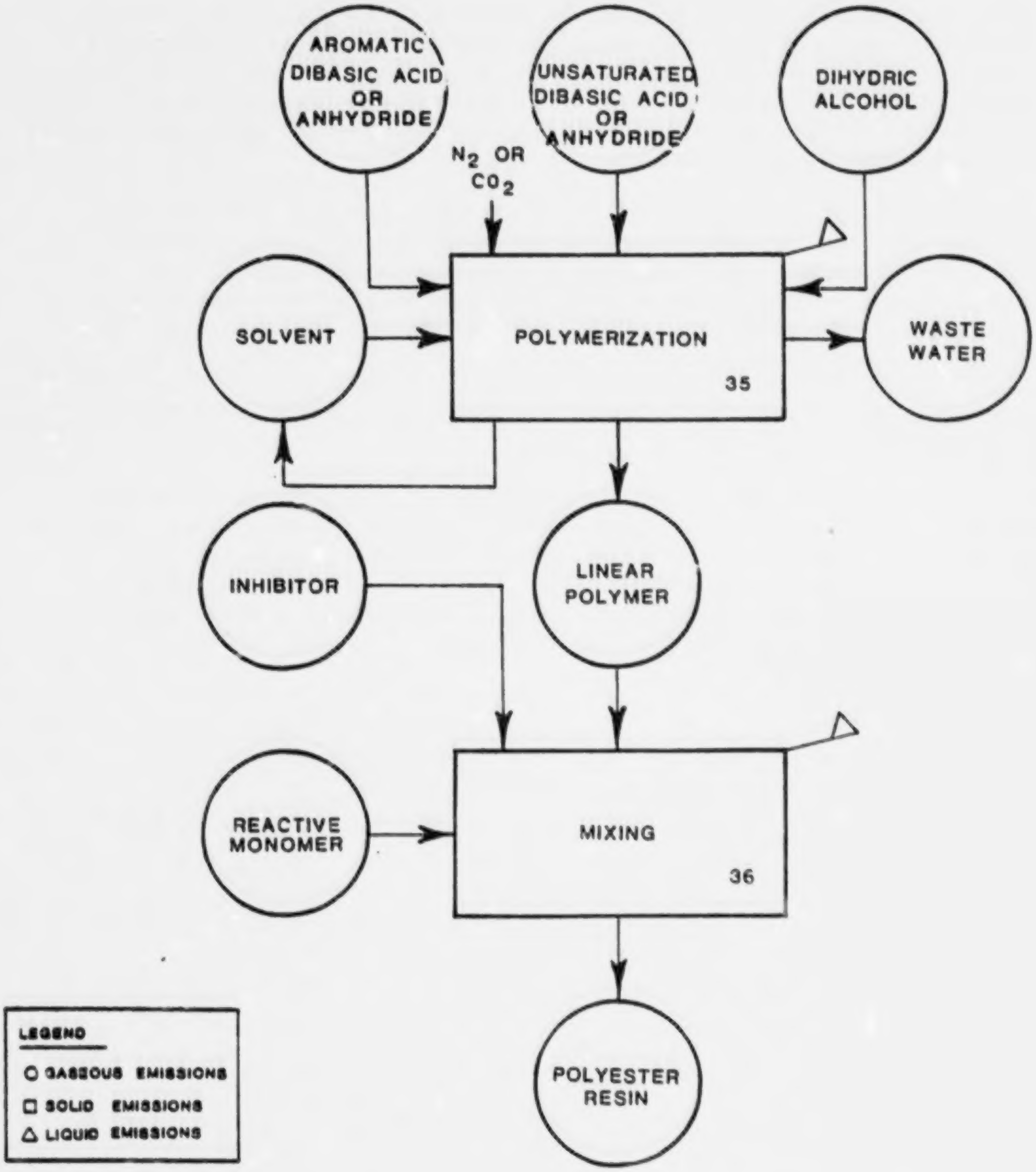

AROMATIC DIBASIC ACID OR ANHYDRIDE
UNSATURATED DIBASIC ACID OR ANHYDRIDE
DIHYDRIC ALCOHOL
N_2 OR CO_2
SOLVENT
POLYMERIZATION
35
WASTE WATER
INHIBITOR
LINEAR POLYMER
REACTIVE MONOMER
MIXING
36
POLYESTER RESIN
LEGEND
○ GASEOUS EMISSIONS
□ SOLID EMISSIONS
△ LIQUID EMISSIONS

FIGURE 14 . UNSATURATED POLYESTER RESIN PRODUCTION

Polymerization

1. Function - An aromatic dibasic acid or anhydride, an unsaturated dibasic acid or anhydride, and a dihydric alcohol are charged to a stainless steel or glass-lined reactor equipped with an agitator, a condenser, inert gas facilities, fume scrubbers, sampling devices, and a heat source. The temperature is raised, and the reaction is allowed to continue in an inert atmosphere until acid number or viscosity measurement specifications are met.

The water of reaction is removed by one of two alternate methods. The fusion process removes water and maintains an inert atmosphere by sparging with nitrogen or carbon dioxide. The other method, commonly called the solvent or azeotropic method, involves the addition of a solvent and distillation of the water and solvent as an azeotrope during the reaction. The solvent is then recovered for recycle.

The overhead vapors from the reactor are sometimes scrubbed for removal of entrained liquids and solids.

2. Input Materials - The most commonly used unsaturated dibasic acids are maleic and fumaric acids, generally provided in the form of anhydrides. The most common aromatic dibasic acid in use is phthalic acid. However, isophthalic, adipic, and azelaic acids are also used. The dihydric alcohol may be ethylene glycol, diethylene glycol, propylene glycol, dipropylene glycol, neopentyl glycol, or some similar compound. A typical polyester resin has input materials listed in Table 29.

Table 29. POLYESTER RESIN FEED MATERIALS

Feed Material	Resin A[a]	Resin B[a]	Resin C[b]
Phthalic anhydride	28.86	40.5	3
Maleic anhydride	19.11	26.7	5
Propylene glycol	14.83	43.8	-
Ethylene glycol	12.10	-	4
Diethylene glycol	-	-	4

[a] In kg/100 kg resin

[b] In moles

Source: Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

3. Operating Parameters - In the preparation of Resin C in Table 29 the temperature is raised to 375°C with nitrogen or carbon dioxide sparging until an acid number of 60 to 65 is achieved. The temperature is then raised to 440°C and maintained until an acid number of 45 to 50 is reached. The total reaction time is about 5 hours. At the end of this time the temperature is reduced to 150°C in preparation for mixing with a cross-linking agent.

4. Utilities - See Table 28.

5. Waste Streams - Liquid waste streams result from this process. The water of reaction must be disposed of whether removed by azeotropic or fusion methods. Contaminants include glycols, acids, and solvents.

Scrubbing the reactor overhead streams results in an aqueous waste stream. The concentrations of contaminants will depend on whether the mode of operation is once-through or recirculating. Recirculating scrubber waste may be as high as 200,000 to 400,000 ppm in BOD and COD. These high concentrations are often discharged to landfill or are treated in incineration operations.

Caustic solutions are used to clean reactors, tank cars, and tank trucks. This solution is generally recycled but must be disposed of eventually.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Bannerman, D. G., and E. E. Magat. Polyamides & Polyesters. In: Polymer Processes, Vol X. Calvin E. Schildknect, ed. N.Y., Interscience Publishers, 1956, P. 235-94.

(2) Billmeyer, Fred W., Jr. Textbook of Polymer Science, 2nd Ed. N.Y., Wiley, 1971.

(3) Environmental Protection Agency, Effluent Guidelines Division. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Polymers Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-75/036-b. Washington, D. C., Jan. 1975.

(4) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(5) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 292.

(6) Sittig, Marshall. Pollution Control in the Plastics and Rubber Industry. Park Ridge, N.J., Noyes Data Corp., 1975.

Mixing

1. Function - When the polymerization reaction (Process No. 35) has reached the desired stage, the reactor contents are transferred to a tank for mixing with a reactive solvent or monomer, usually styrene. An inhibitor may be added to prevent preliminary polymerization. The mixture is then cooled and stored in drums or tanks. The final curing is done at the point of application.

2. Input Materials - The linear polymer from Process No. 35, reactive monomer, and often an inhibitor are feed materials to this process. Styrene is most often used as a reactive monomer or solvent; although, methyl methacrylate and vinyl toluene are also used. Inhibitors in commercial use include hydroquinone, p-t-butyl catechol, phenolic resins, aromatic amines, pyrogallol, chloranil, picric acid, and quinones. Resin C of Table 29 is mixed with 6.5 moles of styrene containing 0.02 percent (based on the total solution) p-t-butyl catechol. Resin A of Table 29 requires 30 kg styrene per 100 kg resin and a trace of hydroquinone.

3. Operating Parameters - In mixing resin C of Table 29 the temperature is maintained at 40°C. It is cooled to 20°C before it is pumped to storage facilities.

4. Utilities - See Table 28.

5. Waste Streams - Caustic solutions are used to clean out the storage vessels. Although this is recycled, it eventually ends up as a waste stream. It may be landfilled or incinerated. Spills and leaks during transfer are another source of emissions.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Billmeyer, Fred W., Jr. Textbook of Polymer Science, 2nd Ed. N.Y., Wiley, 1971.

(2) Boenig, H. V. Polyesters, Unsaturated. In: Encyclopedia of Polymer Science & Technology, Vol 2. H. F. Mark, ed. N.Y., Wiley, 1969, p. 129-68.

(3) Environmental Protection Agency. Effluent Guidelines Division. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Polymers Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-75/036-b. Washington, D. C., Jan. 1975.

(4) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(5) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 292.

(6) Sittig, Marshall. Pollution Control in the Plastics and Rubber Industry. Park Ridge, N.J., Noyes Data Corp., 1975.

ALKYD RESIN PRODUCTION PROCESSES

The term "alkyd" in the plastics and resins industry has a fairly narrow connotation which has evolved through usage. Alkyd resins are specific polyester resins formed from polyhydric alcohols, polybasic acids, and fatty acids. These compounds are usually produced in hydrocarbon solvent solutions. A large amount of the production of alkyds is ultimately blended with other resins. Varying amounts of different reactants makes possible an almost limitless number of products with different characteristics.

The alkyd resins are often manufactured in the same plants and even in the same reactors as the unsaturated polyesters. They have similar chemistries, processing, and waste problems. Figure 15 is a flow sheet included as an aid in understanding the processing sequence in making alkyd resins. The similarity to Figure 14 of the unsaturated polyester operation is notable; the differences occur in the reactants and solvents used.

Waste water loading for alkyd resin production is 0.3 to 12.0 m^3/Mg. Raw waste loads include BOD_5, 9 to 25 kg/Mg; COD, 15 to 80 kg/Mg; and suspended solids, 1 to 2 kg/Mg.

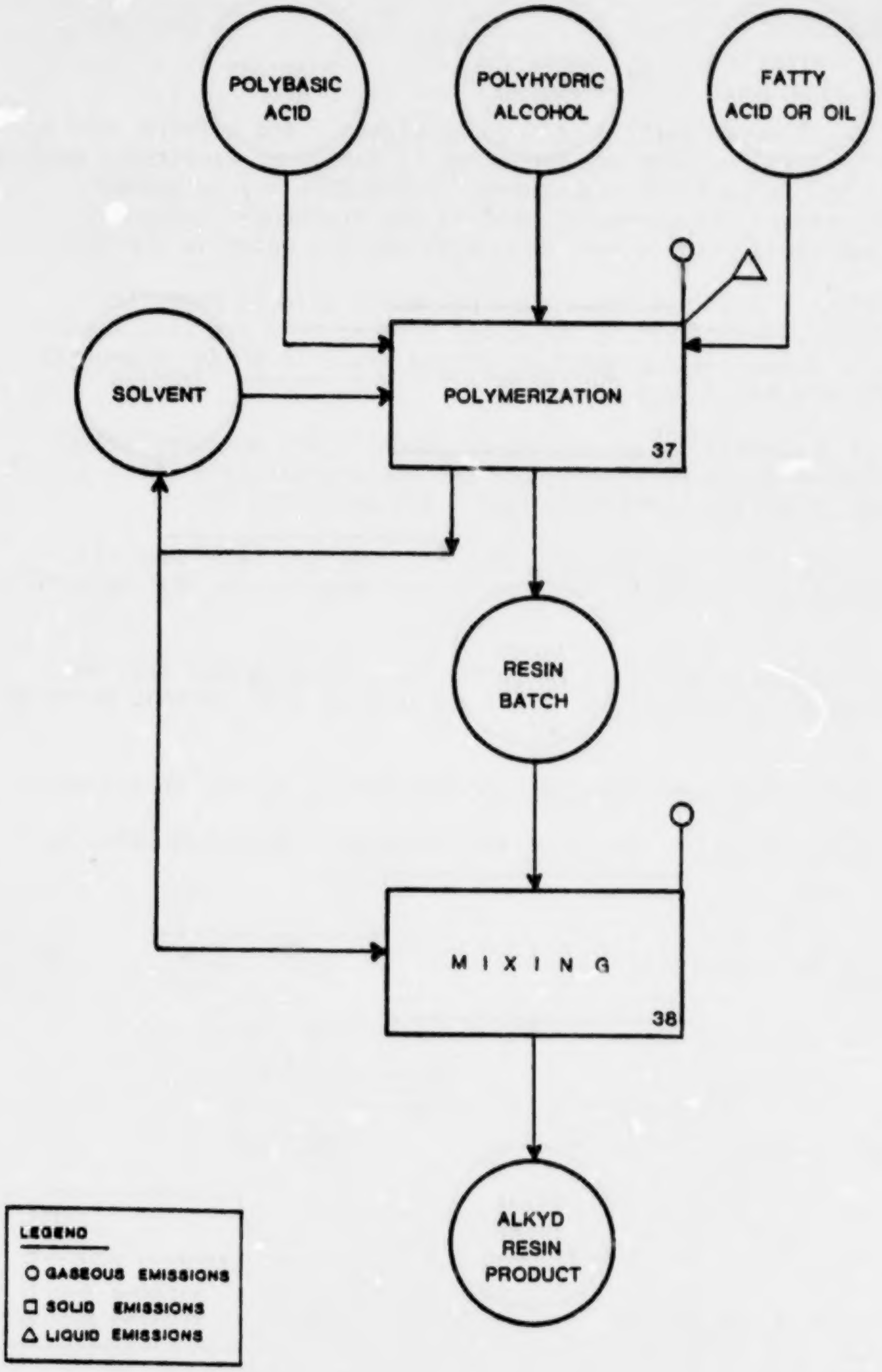

POLYBASIC ACID
POLYHYDRIC ALCOHOL
FATTY ACID OR OIL
SOLVENT
POLYMERIZATION
37
RESIN BATCH
MIXING
38
ALKYD RESIN PRODUCT
LEGEND
○ GASEOUS EMISSIONS
□ SOLID EMISSIONS
△ LIQUID EMISSIONS

FIGURE 15. ALKYD RESIN PRODUCTION

Polymerization

1. Function - A polybasic acid, a polyhydric alcohol, and a fatty acid or oil are charged to a reactor and are processed by fusion or azeotropic methods (See Process No. 35) in an inert atmosphere. The kettle may be heated directly or indirectly. The condenser used in the azeotropic method is usually a tube and shell, single pass type with cooling water in the shell.

2. Input Materials - The most often used polybasic acid is phthalic anhydride; isophthalic acid, adipic acid, and sebacic acid are also used. Maleic and fumaric acids may replace part of the aromatic acids in amounts up to 10 percent on a molar basis.

The two most frequently used polyhydric alcohols are pentaerythritol and glycerol. Others which have been used include dipentaerythritol, trimethylolethane, sorbitol, ethylene glycol, and propylene glycol.

Fatty acids and oils in common use include soya oil, safflower oil, castor oil, linseed oil, coconut coil, cottonseed fatty acids, and tall oil fatty acids.

Metal salts are sometimes used as catalysts. Litharge and lithium compounds are common. Concentrations used are 0.01 to 0.05 percent based on the triglyceride oil.

Solvents used in the azeotropic method are usually xylene or toluene.

A typical alkyd resin is made from feed materials described below in Table 30.

Table 30. FEED MATERIALS FOR A TYPICAL ALKYD RESIN

Feed Materials	Parts by Weight
linseed oil	2000
glycerol	580
lime	2
phthalic anhydride	1400

3. Operating Parameters - Reaction temperatures range from 210 to 280°C.

A pitched-blade, fan-type turbine is widely used for agitation. A useful turbine diameter is 35 to 50 percent of that of the kettle. A peripheral speed of 3 to 4 m/sec (600 to 800 ft/min) is used.

Inert gas flow rate is usually 0.04 to 0.3 $m^3/min/m^3$ (0.005 to 0.04 $ft^3/min/gal$) of reactants.

The shell and tube condenser must provide 2 m^2 (20 ft^2) condensing area for a 4 m^3 (1000 gal) kettle.

Xylene returns to the reactor from the condenser at 25 to 40°C.

4. Utilities - None were available in the sources consulted for this study.

5. Waste Streams - Scrubbing the reactor overhead stream produces waste water which contains reactants and solvent. Water of reaction removed from the kettle forms another liquid waste stream. Kettle cleaning with caustic or solvents between batches also contributes to the liquid waste stream from the plant. The cleaning solutions are generally recycled but eventually end up as waste to be disposed of. This source of waste is reported to be the major source of waste water from alkyd resin production.

The waste water production from alkyd resin manufacture is about 15 m^3 (4000 gal) per 0.90 Mg (one ton) of product. About 5.5 kg (12 lb) of cleaning solution are disposed of per 0.90 Mg (one ton) of product.

Gaseous emissions of solvent and reactants may occur at the scrubber vent. The high processing temperatures approach the boiling points of many of the reactants.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Environmental Protection Agency. Effluent Guidelines Division. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Polymers Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-75/036-b. Washington, D. C., Jan. 1975.

(2) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(3) Mraz, Richard G. and Raymond P. Silver. Alkyd Resins. In: Encyclopedia of Polymer Science and Technology, Vol 1. H. F. Mark, ed. N.Y., Wiley, 1964, p. 663-734.

(4) Sittig, Marshall. Pollution Control in the Plastics and Rubber Industry. Park Ridge, N.J., Noyes Data Corp., 1975.

(5) Unit Processes in Organic Synthesis, 5th Ed. Philip H. Groggins, ed. N.Y., McGraw-Hill, 1958, p. 943-1035.

Mixing

1. Function - When the polymerization reaction (Process No. 37) reaches the desired stage, the batch is dropped into a jacketed, agitated tank equipped with a condenser. The reaction products are cooled and diluted to the desired resin content. The cooled, diluted resin is then filtered and transferred to drums or tanks for storage prior to sale.

2. Input Materials - The alkyd resin from the reactor and a solvent such as toluene or xylene are feed materials to this process.

3. Operating Parameters - The volume of the thinning tank must be twice the volume of the reactor. Agitation is probably accomplished with a turbine agitator. A condenser should be provided to recover volatilized vapors.

4. Utilities - None were detailed in the sources consulted for this study.

5. Waste Streams - Fugitive gaseous emissions may result from the condenser. The gaseous emissions may contain solvent and reactant vapors.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Environmental Protection Agency. Effluent Guidelines Division. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Polymers Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-75/036-b. Washington, D.C., Jan. 1975.

(2) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(3) Mraz, Richard G. and Raymond P. Silver. Alkyd Resins. In: Encyclopedia of Polymer Science and Technology, Vol 1. H. F. Mark, ed. N.Y., Wiley, 1964. p. 663-734.

(4) Sittig, Marshall. Pollution Control in the Plastics and Rubber Industry. Park Ridge, N.J., Noyes Data Corp., 1975.

(5) Unit Processes in Organic Synthesis, 5th Ed. Philip H. Groggins, ed. N.Y., McGraw-Hill, 1958, p. 943-1035.

POLY(ETHYLENE TEREPHTHALATE) PRODUCTION PROCESSES

This operation treats the producion of poly(ethylene terephthalate) which is used almost exclusively in the synthetic fiber industry. Poly (butylene terephthalate) is another thermoplastic polyester of the same type which is becoming increasingly important. Almost no information was available in the references consulted, however, concerning its production and resultant environmental problems. Because of the lack of information, this treatment is necessarily restricted to poly (ethylene terephthalate) production. The products of this operation take the form of chips and fibers spun directly from the molten polymer. Although batch and continuous processes are both in use, the trend for new operations is toward continuous processes integrated with spinning equipment for production of fibers (see Synthetic Fibers Industry, Chapter 11).

The use of terephthalic acid (TPA) has become an alternative to the use of dimethyl terephthalate (DMT) as a raw material. Economic advantages indicate the use of TPA in new plants. In spite of the economic advantages in the use of continuous processes and TPA as a raw material, a large amount of poly (ethylene terephthalate) is still produced in existing plants using DMT in a batch process representing the older technology.

Estimates of utility requirements for production of poly (ethylene terephthalate) from DMT and TPA are presented in Table 31.

Table 31. UTILITY REQUIREMENTS FOR POLY(ETHYLENE TEREPHTHALATE)[a]

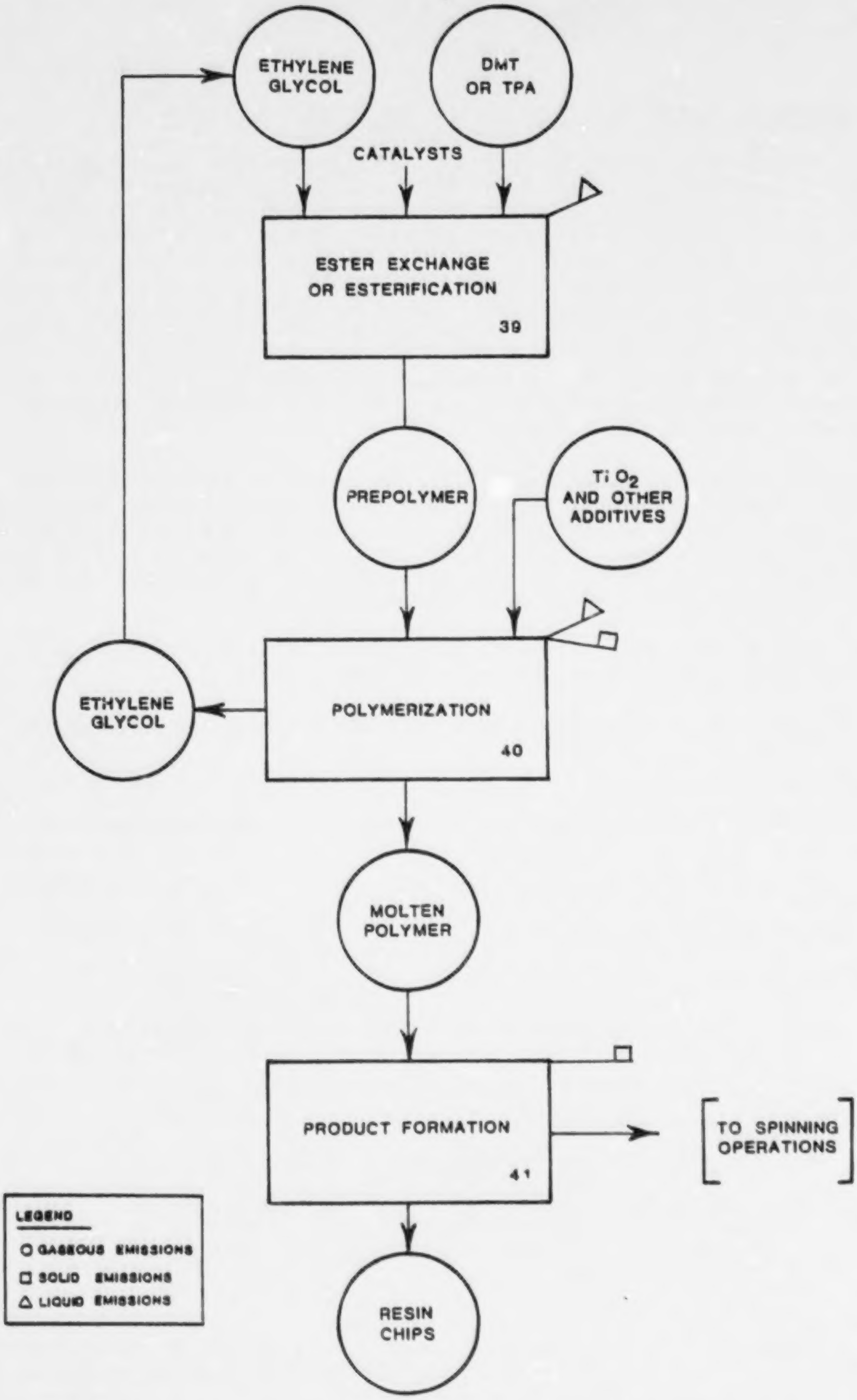
	TPA, continuous process	DMT, batch process
cooling water	247 m^3(65,300 gal)/hr	251 m^3(66,400 gal)/hr
makeup water[b]	11 m^3(2800 gal)/hr	12 m^3(3200 gal)/hr
electricity	64-850 kW	850.8 kW
fuel	358 m^3/hr(13,400 scfh)	6.88 Mg (15,160 lb)/hr 206 m^3/hr (7,300 cfh)

[a] Based on 38 Mg (83,000 lb)/yr capacity

[b] Includes cooling water and steam requirements

Source: Hedley, W.H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

Figure 16 is a flow sheet illustrating the processes involved in this operation. The production of poly(ethylene terephthalate) is accomplished in three processes: 39) Ester exchange or esterfication, 40) Polymerization, and 41) Product Formation. In integrated plants the spinning process consumes most of the production.



ETHYLENE GLYCOL
DMT OR TPA
CATALYSTS
ESTER EXCHANGE OR ESTERIFICATION
39
PREPOLYMER
Ti O_2 AND OTHER ADDITIVES
ETHYLENE GLYCOL
POLYMERIZATION
40
MOLTEN POLYMER
PRODUCT FORMATION
41
TO SPINNING OPERATIONS
RESIN CHIPS
LEGEND
○ GASEOUS EMISSIONS
□ SOLID EMISSIONS
△ LIQUID EMISSIONS

FIGURE 16. POLY (ETHYLENE TEREPHTHALATE) PRODUCTION

POLY(ETHYLENE TEREPHTHALATE) PRODUCTION PROCESS NO. 39

Ester Exchange or Esterification

1. Function - In the batch process which is widely used, dimethyl terephthalate (DMT) or terephthalic acid (TPA), catalysts and ethylene glycol are charged to a heated, agitated, glass-lined or stainless steel kettle equipped with a condenser, a vacuum system, and an inert gas system. The temperature is raised to initiate the reaction. The DMT reaction produces a by-product of methanol which is removed as it forms along with refluxed ethylene glycol.

Continuous processes have been developed and newer plants employ these processes. Molten DMT or TPA, catalysts, and ethylene glycol are charged to a horizontal sectioned reactor operated with a temperature gradient or to a column equipped with a condenser and reboiler. The column condenser is equipped with capabilities to separate water and glycol; pressure rectification is one indicated method. The glycol is recycled to the column after purification and the water becomes a waste stream.

2. Input Materials - Molar ratios of ethylene glycol to DMT are reported by one source as 2.1 to 2.2. Another source cites requirements of 0.909 Mg (2,002 lb) DMT and 0.632 Mg (1,391 lb) of ethylene glycol per ton of product resin. The glycol to TPA mole ratio is generally lower: 1.3 to 1.5. Requirements of 0.781 Mg (1,721 lb) of TPA and 0.50 Mg (1,111 lb) of ethylene glycol per 0.9 Mg (one ton) of product are reported.

3. Operating Parameters - The batch reactor of 0.4 to 23 Mg (0.5 to 25 ton) capacity is heated to 150 to 210°C for DMT processes. Temperatures of 200-250°C are reported for TPA systems at a pressure of 0.2 to 1.0 MPa (2 to 10 atm). The continuous process has a temperature gradient from 170° to 245°C (338°F to 473°F) and requires 4 hours for reaction. The process is conducted at atmospheric pressure. Catalysts for this process and for Process No. 40, Polymerization, are both added here and include oxides, carbonates, and acetates of zinc, calcium, manganese, magnesium, cobalt and antimony. The quantities used are generally 0.05 to 0.1% based on the weight of DMT.

4. Utilities - See Table 31.

5. Waste Streams - Water from the condenser forms a waste stream contaminated with the reactor contents. The treatment and/or disposition of this stream is unspecified in the literature consulted for this study.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Brownstein, Arthur M. The Xylenes. In: U.S. Petrochemicals. Arthur M. Brownstein, ed. Tulsa, OK, The Petroleum Publishing Co., 1972, p. 192-210.

(2) Dux, James P. Polyester Fibers. In: Chemical and Process Technology Encyclopedia. Douglas M. Considine, ed. N.Y., McGraw-Hill 1974, p. 896-97.

(3) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(4) Goodman, I. Polyesters. In: Encyclopedia of Polymer Science and Technology, Vol 11. H. F. Mark, ed. N. Y., Wiley, 1969, p. 110-17.

(5) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(6) Rodriguez, Ferdinand. Principles of Polymer Systems. N.Y., McGraw-Hill, 1970.

(7) Unit Processes in Organic Synthesis, 5th Ed. Philip H. Groggins, ed. N.Y., McGraw-Hill, 1958, p. 943-1035.

POLY(ETHYLENE TEREPHTHALATE) PRODUCTION — PROCESS NO. 40

Polymerization

1. Function - Before polymerization or polycondensation takes place, additions of toners, optical brighteners, delusterants, and other substances are made. Titanium oxide is commonly added as a delusterant, as most of the production is used for polyester fibers.

The temperature and pressure are then adjusted to initiate the polycondensation reaction. The continuous process utilizes horizontal compartmented reactors with individual agitators. Two series of reactors may be used to effect extensive polymerization. The excess glycol is recovered for recycle.

2. Input Materials - The ester or prepolymer from Process No. 39 and various additives are feeds to this process.

Titanium oxide concentrations range from 0.02 to 2 percent by weight. Triaryl phosphites or phosphates and phenolic compounds may also be added.

3. Operating Parameters - In the batch process the temperature is adjusted to 270 to 280°C, and the pressure is adjusted to 66 to 133 Pa (0.5 to 1 mmHg). Two horizontal reactors in series may be operated at 270°C, 2 to 3kPa (15 to 25 mmHg) and 280 to 285°C, 66 to 133 Pa (0.5 to 1 mmHg), respectively, for continuous modes of operation.

4. Utilities - See Table 31.

5. Waste Streams - Ethylene glycol purification operations are reported to contribute emissions of 2.2 kg (4.8 lb) ethylene, 21 kg (46 lb) of polyethylene glycols, 86 g (0.19 lb) sodium hydroxide and sodium bisulfite, and 86 g (0.19 lb) of other wastes per 0.9 Mg (one ton) of product. The method of purification from which these wastes arise is not specified. The waste stream is described as a solid.

The use of steam ejectors for glycol recovery is indicated. This type of processing produces a fouled condensate or waste-water stream.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Brownstein, Arthur M. The Xylenes. In: U. S. Petrochemicals. Arthur M. Brownstein, ed. Tulsa, OK, The Petroleum Publishing Co., 1972, p. 192-210.

(2) Dux, James P. Polyester Fibers. In: Chemical and Process Technology Encyclopedia. Douglas M. Considine, ed. N.Y., McGraw-Hill, 1974, p. 896-97.

(3) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(4) Goodman, I. Polyesters. In: Encyclopedia of Polymer Science and Technology, Vol 11. H. F. Mark, ed. N.Y., Wiley, 1969, p. 110-17.

(5) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(6) Rodriguez, Ferdinand. Principles of Polymer Systems. N.Y., McGraw-Hill, 1970.

(7) Unit Processes in Organic Synthesis, 5th Ed. Philip H. Groggins, ed. N.Y., McGraw-Hill, 1958, p. 943-1035.

POLY(ETHYLENE TEREPHTHALATE) PRODUCTION

PROCESS NO. 41

Product Formation

1. Function - When the desired molecular weight is reached, the polymer may be transferred to the spinning machinery while still molten (Chapter 11). If a resin product is desired the polymer is extruded and chilled before it is cut or broken into chips.

2. Input Materials - Molten polymer and cooling water are required for this process.

3. Operating Parameters - None were available in the sources consulted for this study.

4. Utilities - See Table 31.

5. Waste Streams - Pelletizing, chipping, and packaging operations are potential sources of particulate emissions. Chilling the polymer may be done by direct or indirect contact with cooling water. If direct contact with water is the method used, a waste-water stream containing polymer fines may result. Details concerning this process were scarce in the sources consulted for this study.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Brownstein, Arthur M. The Xylenes. In: U. S. Petrochemicals, Arthur M. Brownstein, ed. Tulsa, OK, The Petroleum Publishing Co., 1972, p. 192-210.

(2) Dux, James P. Polyester Fibers. In: Chemical and Process Technology Encyclopedia. Douglas M. Considine, ed. N.Y., McGraw-Hill, 1974, p. 896-97.

(3) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(4) Goodman, I. Polyesters. In: Encyclopedia of Polymer Science and Technology, Vol 11. H. F. Mark, ed. N.Y., Wiley, 1969, p. 110-117.

(5) Rodriguez, Ferdinand. Principles of Polymer Systems. N.Y., McGraw-Hill, 1970.

(6) Unit Processes in Organic Synthesis, 5th Ed. Philip H. Groggins, ed. N. Y., McGraw-Hill, 1958, p. 943-1035.

NYLON 6 RESIN PRODUCTION PROCESSES

Nylon 6 is one of the polyamides made by polymerization of an amino acid or a lactam. Other commercially significant nylons of this type are nylon 11 and nylon 12. Nylon 6, the most important product of this type in terms of volume produced, is made from caprolactam. Nylon 11 is derived from 11-aminoundecanoic acid; nylon 12 is made from lauryllactam. The production of the latter two nylons is not discussed in this chapter.

The two different pathways to the production of nylon 6 shown in Figure 17 indicate two different commercial methods of polymer recovery after the polymerization reaction. Both methods, aqueous extraction and vacuum distillation, are continuous methods. However, the vacuum distillation method is suitable for integration with spinning equipment; moreover, the trend in the industry is toward integrated facilities.

Three process descriptions define the operation of making nylon 6: 42) Polymerization, 43) Polymer Isolation (aqueous extraction), and 44) Polymer Isolation (vacuum distillation). These process descriptions are shown in Figure 17, which also indicates waste streams discussed in the process descriptions.

When quantitative waste stream data for each process were unavailable, a qualitative description was included. Waste-water loading for nylon 6 production is reported to be 54.2 m^3/Mg product. Raw waste load data include BOD, 1 to 135 kg/Mg, COD, 1 to 300 kg/Mg; and suspended solids, 0 to 8 kg/Mg. Utility requirements for making nylon 6 resin chips are summarized in Table 32. Although not specifically stated, the process used for monomer recovery appears to be aqueous extraction.

TABLE 32. UTILITY REQUIREMENTS FOR MAKING NYLON 6 RESIN CHIPS[a]

cooling water	2.71 m^3/min (715 gal/min)
steam (100 psig)	4 Mg/hr (9000 lb/hr)
(300°C)	0.54 Mg/hr (1200 lb/hr)
electric power	830 kW
fuel	733 W (2.5 x 10^3 Btu/hr)

[a] 13.6 Mg(30,000 lb)/yr capacity

Source: Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

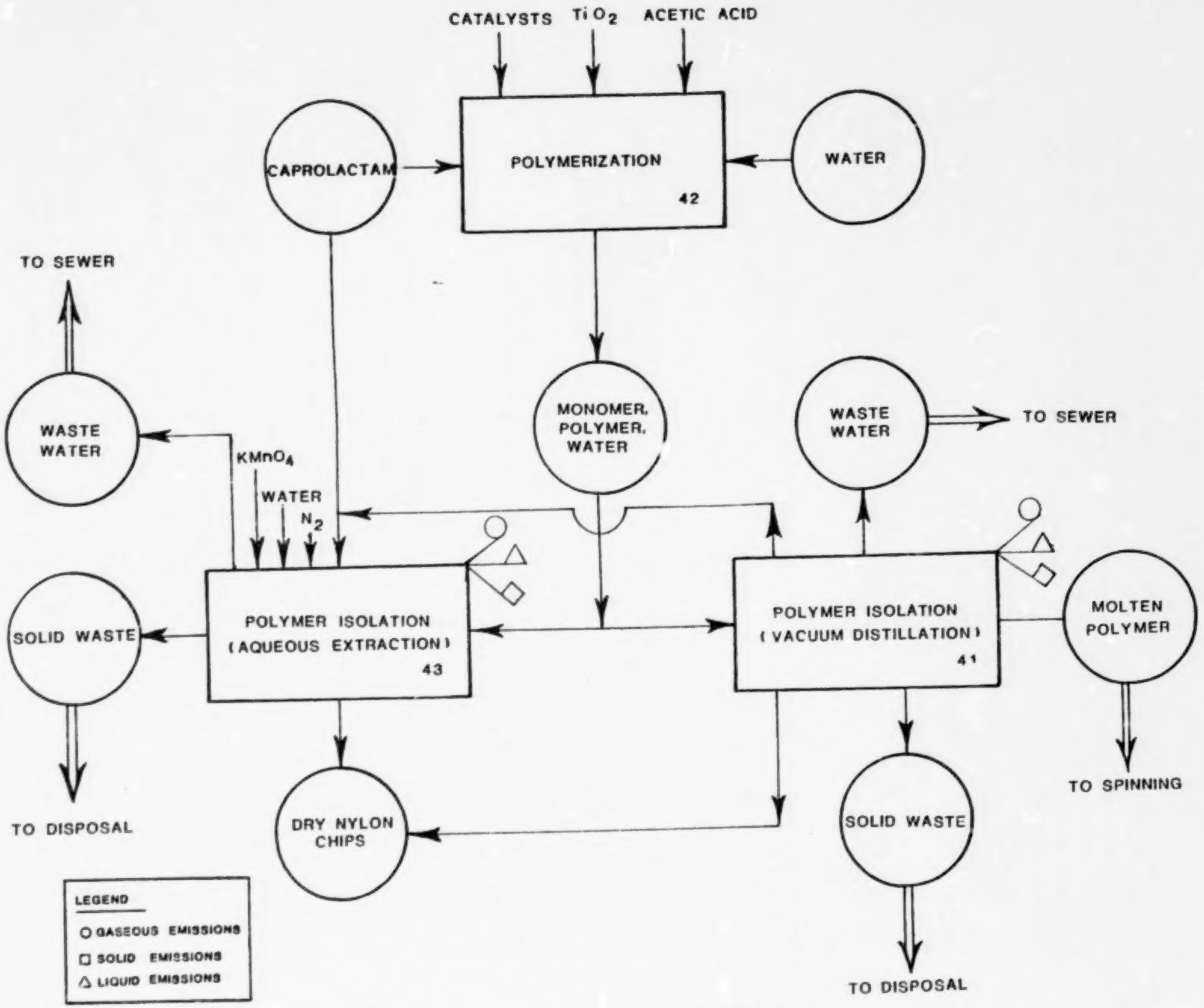

CATALYSTS
TiO_2
ACETIC ACID
CAPROLACTAM
POLYMERIZATION
42
WATER
TO SEWER
WASTE WATER
$KMnO_4$
WATER
N_2
MONOMER, POLYMER, WATER
WASTE WATER
TO SEWER
SOLID WASTE
POLYMER ISOLATION (AQUEOUS EXTRACTION)
43
POLYMER ISOLATION (VACUUM DISTILLATION)
41
MOLTEN POLYMER
TO DISPOSAL
DRY NYLON CHIPS
SOLID WASTE
TO SPINNING
TO DISPOSAL
LEGEND
○ GASEOUS EMISSIONS
□ SOLID EMISSIONS
△ LIQUID EMISSIONS

FIGURE 17. NYLON 6 RESIN PRODUCTION

Polymerization

1. Function - Molten caprolactam, water, catalyst, TiO_2, and acetic acid are charged to a vertical tube reactor. Temperature is controlled by heat exchange with dowtherm. As the reaction mass proceeds slowly down the reactor, polymerization takes place. The effluent, consisting of polymer, unreacted monomer, oligomer, and water, is further processed in Polymer Isolation, Process No. 43.

2. Input Materials - Caprolactam, catalysts, water, stabilizer (acetic acid) and delusterant (TiO_2) are feed materials to the reactor. An operation producing 13.6 Mg (30,000 lb) nylon resin per year is reported to require 0.867 Mg (1,909 lb) caprolactam and 2 kg (4 lb) acetic acid per 0.90 Mg (one ton) of product. Another source of information presents a material balance which specifies a requirement of 1.2 Mg (2600 lb) makeup and recycle caprolactam per 0.90 Mg (one ton) of product. The reasons for the wide variation were not clear.

3. Operating Parameters - The reaction temperature is 250 to 260°C, and the time required is 20 to 24 hrs. Pressure is atmospheric. The vertical reactor is usually 8 to 10 m (26 to 33 ft) tall.

4. Utilities - See Table 32.

5. Waste Streams - Caprolactam emissions to the atmosphere may occur at mixing tank vents and at reactor vents. Average emission factors compiled by EPA from questionnaire responses indicate 0.00012 kg caprolactam emitted at the mixing tank vent and 0.00034 kg caprolactam emitted at the reactor vent per kg nylon 6 produced.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(2) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(3) Kohan, Melvin I., ed. Nylon Plastics. New York, Wiley-Interscience, 1973.

(4) Pervier, J. W., et al. Survey Reports on Atmospheric Emission from the Petrochemical Industry, 4 Vols. EPA 450/3-73-005 a-d, Contract No. 68-02-0255. Air Products & Chemicals, Houdry Div., March 1974.

(5) Sweeny, W. Polyamides (General). In: Kirk-Othmer Encyclopedia of Chemical Technology, Vol 16. Anthony Standen, ed. N.Y., Wiley, 1968, p. 1-46.

(6) Wallace, Peter T. Polyamide Resins. In: Chemical Economics Handbook. Menlo Park, Ca., Stanford Research Institute, March 1974, p. 580.1031A-580.1032F., 580.1032E - 580.1032F.

Polymer Isolation (Aqueous Extraction)

1. Function - The reactor contents from Process No. 42 are extruded from the bottom of the vertical tube reactor. The extruded ribbon is cooled by direct contact with water and is then cut into chips with a rotary cutter. Caprolactam and oligomer are extracted with hot water by countercurrent contact. The polymer chips are dried in a hot nitrogen atmosphere or under vacuum before being stored for use in spinning or molding.

Recovery of caprolactam from the water used for extraction is accomplished in several steps. Concentration by evaporation is effected in multiple stages. The concentrated solution of caprolactam is then treated with potassium permanganate to oxidize impurities which are discarded as solid waste. A distillation process separates the caprolactam for recycle from the water and higher boiling compounds which form waste streams.

2. Input Materials - The polymerization reactor contents, consisting of 10 to 15 percent monomer and oligomer; nitrogen; water for cooling the polymer ribbon and for the extraction process; and permanganate are all needed in this process. Steam may also be required for evaporation and distillation procedures.

3. Operating Parameters - Water temperature for extraction is 90 to 100°C. The aqueous extraction results in a solution which is 5 percent caprolactam. This concentration is increased to 70 percent by evaporation procedures. Drying temperature for the polymer chips is 100 to 120°C.

4. Utilities - See Table 32.

5. Waste Streams - Emissions of caprolactam vapor may occur at several points in this process. When the molten polymer is quenched, caprolactam vapors escape to the atmosphere. One plant responding to an EPA questionnaire reported emissions of 0.00337 kg caprolactam per kg nylon 6 produced. Small amounts of caprolactam vapor are also lost from the dryer vent. The distillation and evaporation procedure for monomer recovery are subject to fugitive losses at seals, valves, and fittings. In addition, the pellet cutting step may emit small amounts of particulate matter to the atmosphere. Atmospheric emissions of caprolactam and nylon particulates from cutting are 0.00272 kg/kg nylon 6 produced.

Solid wastes may be generated as still bottoms in the monomer recovery section. This waste stream is generated at the rate of about 19 g/kg of product and contains oligomer, high-boiling liquids, and about 2 percent caprolactam. The permanganate treatment of the aqueous caprolactam solution results in sludge for disposal. Waste polymer and off-spec product also form solid waste streams. Indications in the literature are that all of the solid waste streams are landfilled.

The water used to extract monomer from the nylon 6 polymer contributes liquid waste which originates at several points. About 98 percent of the water used for extraction is removed in the evaporator. Other sources of waste water are at the dryers and in the distillation for final monomer purification. A range of waste-water parameters from these sources is presented in Table 33.

TABLE 33. CHARACTERISTICS OF AQUEOUS EFFLUENT FROM NYLON 6 RESIN WASHING AND DISTILLATION

BOD_5	0.1-135 g/kg product	0.2-270 lb/ton product
COD	0.2-300 g/kg product	0.4-600 lb/ton product
Suspended Solids	0-8 g/kg product	0-16 lb/ton product

Another source of waste water is found in quenching of the extruded polymer.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(2) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(3) Kohan, Melvin I., ed. Nylon Plastics. New York, Wiley-Interscience, 1973.

(4) Pervier, J. W., et al. Survey Reports on Atmospheric Emissions from the Petrochemical Industry, 4 Vols. EPA 450/3-73-005 a-d, Contract No. 68-02-0255. Air Products & Chemicals, Houdry Div., March 1974.

(5) Sweeny, W. Polyamides (General). In: Kirk-Othmer Encyclopedia of Chemical Technology, Vol 16. Anthony Standen, ed. N.Y., Wiley 1968, p. 1-46.

(6) Wallace, Peter T. Polyamide Resins. In: Chemical Economics Handbook. Menlo Park, Ca., Stanford Research Institute, March 1974, p. 580.1031A-580.1032F., 580.1032E-580.1032F.

NYLON 6 RESIN PRODUCTION PROCESS NO. 44

Polymer Isolation (Vacuum Distillation)

1. Function - Water, unreacted monomer, and oligomer are removed from the molten polymer produced in Process No. 42 by vacuum distillation. This separation may be accomplished in a distillation column or in a thin-film evaporator. The molten polymer may then go directly to spinning operations or may be extruded and chilled in water before pelletizing.

It is assumed that the overheads containing water, monomer, and oligomer are then separated for recycle of caprolactam. In some processes oligomer is depolymerized to provide additional recycle monomer.

2. Input Materials - The reaction products from Process No. 42 consisting of monomer, polymer, and water are the main feed stream to this process. Water for quenching is required in making resin pellets or chips.

3. Operating Parameters - A typical vertical, agitated, thin-film evaporator with non-scraping blades rotates at a speed of 9 to 12 m/sec (30-40 feet/sec). Normal evaporators can handle viscosities up to 300 Pa·s (300,000 cp); evaporation rates for high-viscosity materials may be as low as 100 to 150 kg/hr m^2 (20-30 lb/hr ft^2). Clearances between the blade tip and the shell are usually 0.08 to 0.2 cm (0.03 to 0.10 in). Pressures of 0.7 to 1.3 kPa (5 to 10 mmHg) are used for removal of monomer and water from the nylon 6 polymer.

4. Utilities - Data were not available in the sources consulted for this study. Power is needed for the vacuum system, and steam is required for monomer recovery procedures.

5. Waste Streams - Although it was not specified in the literature consulted for this study, monomer is probably recovered for recycle by distillation and by depolymerization. Excess oligomer and water probably form waste streams from this process. The vacuum recovery system may be a source of fugitive gaseous emissions at valves and fittings. Particulates are a potential emission threat in pelleting or cutting operations.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

References -

(1) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(2) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(3) Kohan, Melvin I., ed. Nylon Plastics. New York, Wiley-Interscience, 1973.

(4) Mutzenburg, A. B. Agitated Thin Film Evaporators, Pt. 1, Thin Film Technology. Chemical Engineering 72:175, (13 Sept. 1965).

(5) Parker, N. Agitated Thin Film Evaporators, Pt. 2, Equipment and Economics. Chemical Engineering 72:179, (13 Sept. 1965).

(6) Pervier, J. W., et al. Survey Reports on Atmospheric Emissions from the Petrochemical Industry, 4 Vols. EPA 450/3-73-005 a-d, Contract No. 68-02-0255. Air Products & Chemicals, Houdry Div., March 1974.

(7) Sweeny, W. Polyamides (General). In: Kirk-Othmer Encyclopedia of Chemical Technology, Vol 16. Anthony Standen, ed. N.Y., Wiley, 1968, p. 1-46.

NYLON 66 RESIN PRODUCTION PROCESSES

This operation is restricted to the discussion of nylon 66 production as it is by far the most significant product of this type. Other nylons of this type having some commercial significance are nylons 610, 612, and 69. All of these nylons are made from hexamethylene diamine and a dibasic acid. Adipic acid is used in nylon 66 production, sebacic for nylon 610, dodecanoic for nylon 612, and pelargonic for nylon 69.

Both batch and continuous operations are represented in Figure 18. Economic conditions favor continuous operation integrated with spinning equipment, but batch production is still in use. New plants are expected to adopt continuous processing methods.

Utility requirements for a continuous nylon 66 operation are listed below in Table 34. The estimates are based on a plant with a 13.6 Mg (30,000 lb)/yr capacity.

Table 34. UTILITY REQUIREMENTS FOR A CONTINUOUS NYLON 66 OPERATION

cooling water	1.46 m^3/min	(386 gal/min)
demineralized water	0.0012 m^3/min	(0.31 gal/min)
steam	3.5 Mg/hr	7600 lb/hr
power	190 kW	
nitrogen	690 m^3/hr	(26,000 scfh)
dowtherm heat	1758 W	(6000 Btu/hr)

Source: Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

Figure 18 is a process flow chart included as an aid to understanding the sequence and interrelation of the six processes described in this operation. The processes included are: 45) Feed Preparation, 46) Evaporation, 47) Polymerization (Batch), 48) Resin Product Preparation, 49) Polymerization (Continous), 50) Product Preparation.

An environmental problem may exist in plant localities due to the formation of a "blue haze." This is caused by particulate and aerosol emissions from various vents throughout the operation. Waste-water loading from nylon 66 production is 0 to 152.3 m^3/Mg. Raw waste load includes BOD_5, 1 to 135 kg/Mg; COD, 1 to 300 kg/Mg; and suspended solids, 0 to 8 kg/Mg.

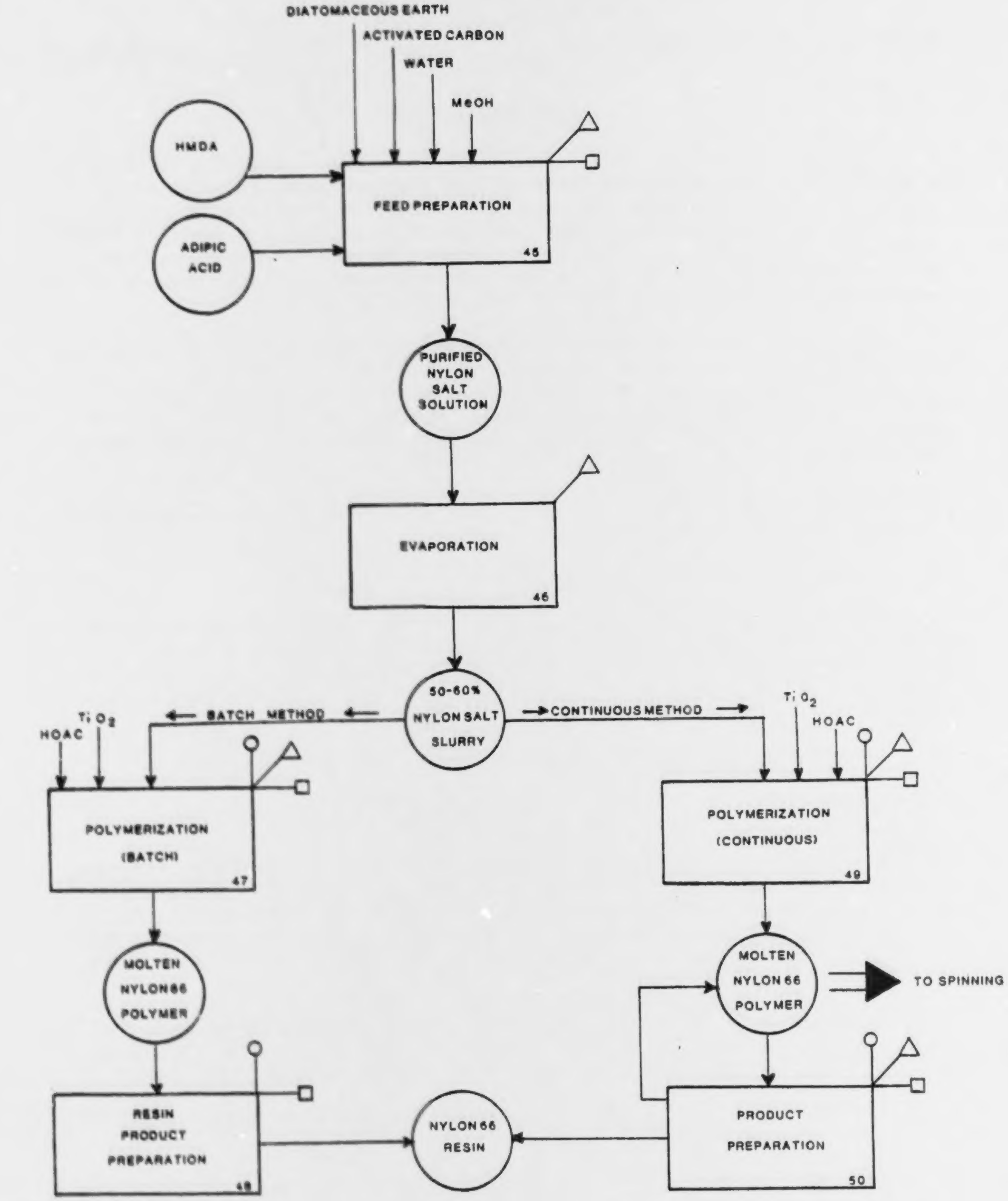

DIATOMACEOUS EARTH
ACTIVATED CARBON
WATER
MeOH
HMDA
ADIPIC ACID
FEED PREPARATION
45
PURIFIED NYLON SALT SOLUTION
EVAPORATION
46
50-60% NYLON SALT SLURRY
BATCH METHOD
CONTINUOUS METHOD
HOAC
TiO_2
POLYMERIZATION (BATCH)
47
POLYMERIZATION (CONTINUOUS)
49
MOLTEN NYLON 66 POLYMER
MOLTEN NYLON 66 POLYMER
TO SPINNING
RESIN PRODUCT PREPARATION
48
NYLON 66 RESIN
PRODUCT PREPARATION
50
LEGEND
○ GASEOUS EMISSIONS
□ SOLID EMISSIONS
△ LIQUID EMISSIONS

FIGURE 18. NYLON 66 RESIN PRODUCTION

Feed Preparation

1. Function - The first step in the batch process for preparing nylon 66 is neutralizing adipic acid with hexamethylene diamine (HMDA) in methanol or water. The resulting nylon salt may be crystallized from methanol solution and dried by centrifugation. Some nylon 66 producers buy a nylon salt solution instead of making the salt from the acid and diamine. In either case the salt solution must then be decolorized with activated carbon before use to remove impurities which would discolor the product polymer.

2. Input Materials - Hexamethylene diamine and adipic acid or hexamethylene diamine adipate (nylon salt) are inputs to this process. Water and activated carbon are also required. If a crystalline material is desired, methanol is used for crystallization. Feed materials required for 0.9 Mg (one ton) of product are estimated to be 0.47 Mg (1043 lb) of HMDA, 0.590 Mg (1299 lb) of adipic acid, and 10.7 kg (26.3 lb) of methanol.

3. Operating Parameters - Data were not available in the sources consulted for this study.

4. Utilities - See Table 34.

5. Waste Streams - Decolorizing results in liquid and solid waste streams. Effluents contain spent carbon, diatomaceous earth, and some nylon salt. Quantitative estimates of 14 kg (30 lb) of carbon and 2.9 kg (6.3 lb) of nylon salt per 0.90 Mg (one ton) of nylon 66 produced are reported by one reference for a plant producing 14 Mg (30,000 lb) per year.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(2) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(3) Kohan, Melvin I., ed. Nylon Plastics. New York, Wiley-Interscience, 1973.

(4) Pervier, J. W., et al. Survey Reports on Atmospheric Emissions from the Petrochemical Industry, 4 Vols. EPA 450/3-73-005 a-d, Contract No. 68-02-0255. Air Products & Chemicals, Houdry Div., March 1974.

(5) Sweeny, W. Polyamides (General). In: Kirk-Othmer Encyclopedia of Chemical Technology, Vol 16. Anthony Standen, ed. N.Y., Wiley, 1968, p. 1-46.

(6) Wallace, Peter T. Polyamide Resins. In: Chemical Economics Handbook. Menlo Park, Ca., Stanford Research Institute, March 1974, p. 580.1031A-580.1032E.

(7) Work, Robert W. Man-Made Textile Fibers. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 323-24.

Evaporation

1. Function - The aqueous suspension of nylon salt from Process No. 45 is fed to a steam-heated evaporator operated in a continuous or batch mode for concentration. One source specifies the use of an agitated, thin-film evaporator.

2. Input Materials - An aqueous nylon salt slurry is the feed to this process; the concentration is usually about 10 percent.

3. Operating Parameters - The concentrated slurry is generally 50 to 60 percent nylon salt in the batch process, but it may range as high as 75% solids. The bulk of the water is removed in the continuous method. A temperature of 110°C (230°F) is reported in the use of a thin-film evaporator.

4. Utilities - See Table 34. Steam is required for the evaporator.

5. Waste Streams - The water vapor removed by the evaporator is condensed and sent to the sewer. The liquid waste stream contains up to one percent HMDA and is one of the major sources of BOD in the aqueous waste from the plant. Additional contaminants in the waste water are reported by one source; 2.4 kg (5.2 lb) methanol; 4 kg (8 lb) nylon salt; and 1.4 kg (3.1 lb) of other impurities including glutaric acid, succinic acid, acetic acid, 1,2-cyclohexanediamine per 0.90 Mg (one ton) of nylon 66 produced. An EPA summary of emissions based on replies to questionnaires indicates an emission of 0.000333 kg of particulates and aerosols per kg of nylon produced. These particulates and aerosols contain HMDA, adipic acid, nylon salt, nylon polymer, cyclopentanone, halide, and sulfonamide and are responsible for the "blue haze" formation in the plant.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(2) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(3) Kohan, Melvin I., ed. Nylon Plastics. New York, Wiley-Interscience, 1973.

(4) Pervier, J. W., et al. Survey Reports on Atmospheric Emissions from the Petrochemical Industry, 4 Vols. EPA 450/3-73-005 a-d, Contract No. 68-02-0255. Air Products & Chemicals, Houdry Div., March 1974.

(5) Sweeny, W. Polyamides (General). In: Kirk-Othmer Encyclopedia of Chemical Technology, Vol 16. Anthony Standen, ed. N.Y. Wiley, 1968, p. 1-46.

(6) Wallace, Peter T. Polyamide Resins. In: Chemical Economics Handbook. Menlo Park, Ca., Stanford Research Institute, March 1974, p. 580.1031A-580.1032E.

(7) Work, Robert W. Man-Made Textile Fibers. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 323-24.

Polymerization (Batch)

1. Function - Batch polymerization generally takes place in an indirectly heated, stirred autoclave reactor. The concentrated slurry from Process No. 46 and additives such as acetic acid and titanium dioxide are charged to the reactor after it is purged with inert gas. The temperature is raised, and the pressure is maintained by a steam bleed vent. When the reaction is complete the pressure is lowered to remove the remaining water. The vapor from the reactor may be scrubbed with water. The scrubber water and the condensate form a waste stream for treatment and disposal.

2. Input Materials - The 50 to 75 percent nylon salt slurry is a feed stream to this process. Also added are chain terminator (acetic acid) and delustrant (TiO_2), plasticizers, pigments, and other additives.

3. Operating Parameters - Reaction temperature is 260 to 280°C. Reactor pressure is held at 1.83 MPa (250 psig). Reaction time is two to three hours.

4. Utilities - No data were available for the batch process in the sources consulted for this study.

5. Waste Streams - The steam from the reactor and the scrubber water, if scrubbing is practiced, are combined to form a liquid waste stream containing HMDA and small amounts of monomer and polymer. If the steam is vented to the atmosphere, the contaminants may cause a "blue haze" as well as an odor problem. An EPA summary of emissions based on replies to questionnaires indicates emissions of particulates and aerosols (including HMDA, adipic acid, nylon salt, polymer, cyclopentanone, halide and sulfonamide) amounting to 0.002100 kg/kg nylon 66 produced. This number is assumed to be for uncontrolled emissions. Another liquid waste stream is formed during reactor cleaning by washing with acetic acid.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(2) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(3) Kohan, Melvin I., ed. Nylon Plastics. New York, Wiley-Interscience, 1973.

(4) Pervier, J. W., et al. Survey Reports on Atmospheric Emissions from the Petrochemical Industry, 4 Vols. EPA 450/3-73-005 a-d, Contract No. 68-02-0255. Air Products & Chemicals, Houdry Div., March 1974.

(5) Sweeny, W. Polyamides (General). In: Kirk-Othmer Encyclopedia of Chemical Technology, Vol 16. Anthony Standen, ed. N.Y., Wiley 1968, p. 1-46.

(6) Wallace, Peter T. Polyamide Resins. In: Chemical Economics Handbook. Menlo Park, Ca., Stanford Research Institute, March 1974, p. 580.1031A-580.1032E

(7) Work, Robert W. Man-Made Textile Fibers. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 323-24.

Resin Product Preparation

1. Function - When the desired molecular weight is reached, the polymer from Process No. 47 is removed from the bottom of the reactor under a nitrogen atmosphere. Chilling is accomplished quickly by direct contact with water. The polymer is band cast and the ribbon is cut or chipped before it is sent to blending and/or storage.

2. Input Materials - The molten polymer from the polymerization reactor and cooling water are required for this process.

3. Operating Parameters - Data were not available for the batch method in the sources consulted for this study.

4. Utilities - Data were not available for the batch method in the sources consulted for this study.

5. Waste Streams - Pelleting and flaking procedures, pneumatic conveying methods, and dry blending procedures are potential sources of particulate emissions.

The once-through cooling water for the casting section forms a liquid waste stream containing polymer fines. One plant indicated, in answering an EPA questionnaire, that this waste stream is generated at the rate of 0.14 m^3 (36 gal)/min. No indication of the plant capacity was given. Another source indicated that a portion of this waste water may be used as cooling tower makeup water.

Casting scrap forms a solid waste stream which is reportedly incinerated. One plant reports incinerating 0.003 kg nylon scrap per kg produced. Complete incineration would result in 0.00123 kg NO_x per kg nylon 66 produced, but no data were reported on the composition of the incineration gases.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(2) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(3) Kohan, Melvin I., ed. Nylon Plastics. New York, Wiley-Interscience, 1973.

(4) Pervier, J. W., et al. Survey Reports on Atmospheric Emissions from the Petrochemical Industry, 4 Vols. EPA 450/3-73-005 a-d, Contract No. 68-02-0255. Air Products & Chemicals, Houdry Div., March 1974.

(5) Sweeny, W. Polyamides (General). In: Kirk-Othmer Encyclopedia of Chemical Technology, Vol 16. Anthony Standen, ed. N.Y., Wiley 1968, p. 1-46.

(6) Wallace, Peter T. Polyamide Resins. In: Chemical Economics Handbook. Menlo Park, Ca., Stanford Research Institute, March 1974, p. 580.1031A-580.1032E.

(7) Work, Robert W. Man-Made Textile Fibers. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 323-24.

Polymerization (Continuous)

1. Function - Additives such as acetic acid and titanium dioxide along with dewatered monomer from Process No. 46 are fed to tank reactors, tubular columns, or thin-film reactors. The reaction mixture is subjected to elevated temperature and pressure to effect polymerization. Water produced by the reaction is removed as steam. Additional water of reaction is removed by reducing the pressure to atmospheric in a flashing step. The vapor streams consisting of contaminated steam may be scrubbed with water to reduce atmospheric emissions.

2. Input Materials - A concentrated nylon salt slurry from Process No. 46, chain terminator (acetic acid), and delustrant (TiO_2) are feed streams to this process.

3. Operating Parameters - Reaction temperature is 232°C (450°F) and reactor pressure is about 1.5 MPa (200 psig). The flashing step is accomplished at 160°C (320°F) and atmospheric pressure.

4. Utilities - See Table 34.

5. Waste Streams - The water removed as steam forms a liquid waste stream of fouled condensate. If scrubbers treat the vapor stream, the scrubber water also becomes a liquid waste stream.

A summary of emissions prepared from EPA questionnaires lists atmospheric emissions of particulates and aerosols (including hexamethylene diamine, adipic acid, nylon salt, nylon 66 polymer, cyclopentanone, halide, and sulfonamide) as 0.00210 kg from the reactor and 0.001100 kg from the flasher per kg of nylon 66 produced. It is these materials that cause the "blue haze" formation.

Another source indicates emissions of 1.2 kg (2.6 lb) of HMDA per 0.90 Mg (one ton) of nylon 66 produced.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(2) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(3) Pervier, J. W., et al. Survey Reports on Atmospheric Emissions from the Petrochemical Industry, 4 Vols. EPA 450/3-73-005 a-d, Contract No. 68-02-0255. Air Products & Chemicals, Houdry Div., March 1974.

(4) Work, Robert W. Man Made Textile Fibers. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N. Y., Van Nostrand Reinhold, 1974, p. 323-24.

NYLON 66 RESIN PRODUCTION PROCESS NO. 50

Product Preparation

1. Function - In some continuous operations the polymer goes through a finisher at elevated temperature to assume complete polymerization. Molten polymer from a continuous process may go directly to spinning operations as described in Chapter 11, Synthetic Fiber Industry. The polymer may also be cast and pelleted as in the batch method (Process No. 48) to form a resin product.

2. Input Materials - Molten polymer from the flashing step in Process No. 49 is the feed material to this process.

3. Operating Parameters - Finishing takes place at a temperature of 280°C (540°F).

4. Utilities - See Table 34.

5. Waste Streams - The vent from the finisher contributes emissions of particulates and aerosols: 0.044g per kg Nylon 66 produced. This stream is normally not scrubbed.

   Process No. 48 describes casting and pelleting waste streams.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

   (1) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

   (2) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

   (3) Pervier, J. W., et al. Survey Reports on Atmospheric Emissions from the Petrochemical Industry, 4 Vols. EPA 450/3-73-005 a-d, Contract No. 68-02-0255. Air Products & Chemicals, Houdry Div., March 1974.

   (4) Sweeny, W. Polyamides (General). In: Kirk-Othmer Encyclopedia of Chemical Technology, Vol 16. Anthony Standen, ed. N.Y., Wiley, 1968, p. 1-46.

   (5) Work, Robert W. Man-Made Textile Fibers. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 323-24.

POLYURETHAN FOAM PRODUCTION PROCESSES

Polyurethans are produced in the form of elastomers, coatings, and foams. This discussion is restricted to the production of foams as they contribute the largest volume of production to the market. There are two types of foam products: one-shot foams and prepolymer systems. For prepolymer products the crosslinking and foaming steps are done at the point of fabrication. In this respect, polyurethans differ from typical resin products such as molding powders, latices, or polymer solutions.

Polyurethans are produced by the condensation polymerization of polyhydric alcohols and diisocyanates. The actual composition of starting materials employed by polyurethan producers is not clear from the literature consulted for this study. It appears that some polyurethan producers synthesize isocyanates from toluene and aniline, while others purchase amines and phosgenate them to form isocyanates. Others may purchase isocyanates directly.

As shown in Figure 19, there are three process descriptions included in this operation: 51) Phosgenation, 52) Polymerization (one shot), and 53) Polymerization (prepolymer systems). The Phosgenation process, of necessity, relies heavily on data for toluene diisocyanate, as the information was available and it is used in the largest volume.

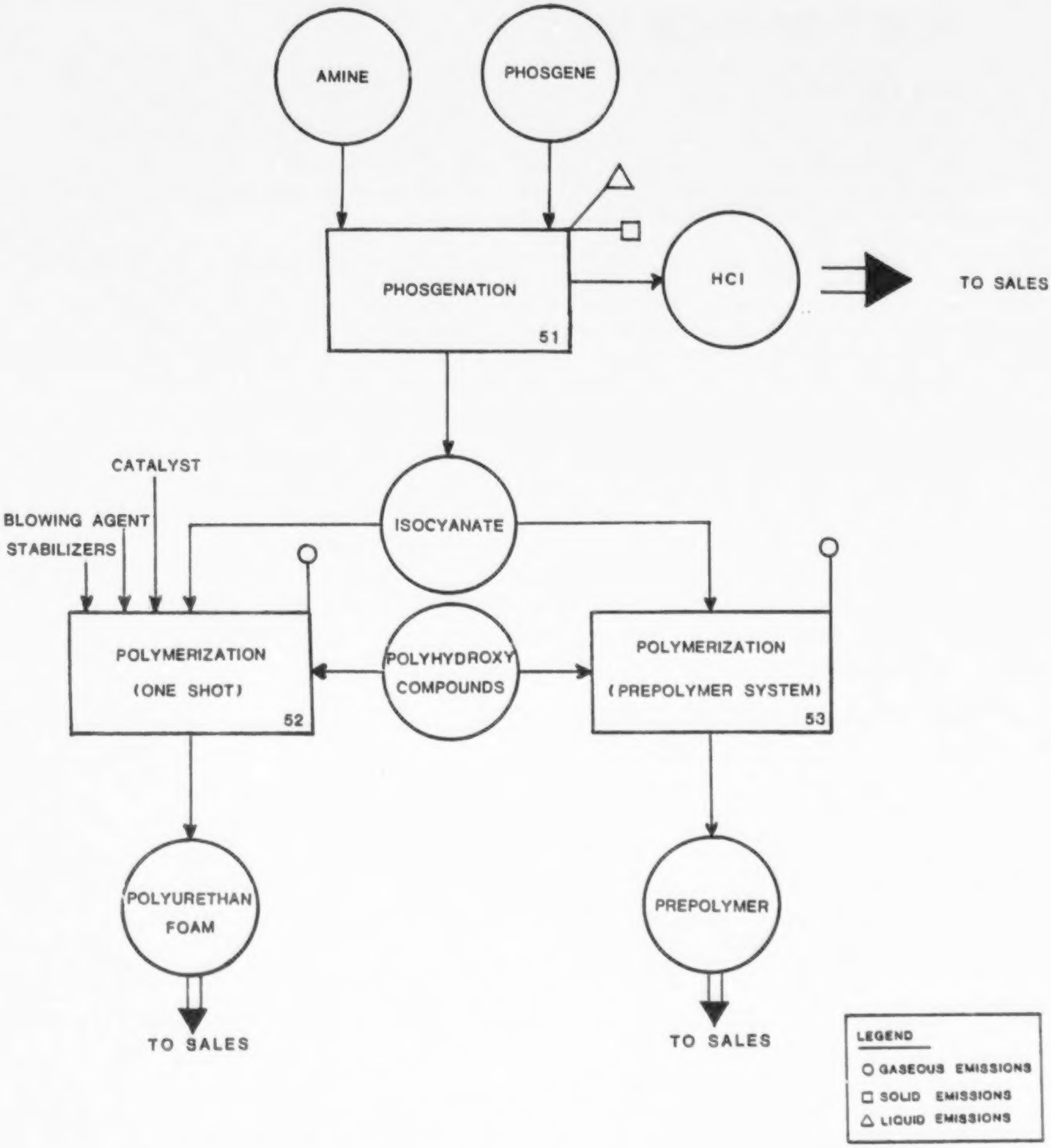

AMINE
PHOSGENE
PHOSGENATION
51
HCl
TO SALES
CATALYST
BLOWING AGENT
STABILIZERS
ISOCYANATE
POLYMERIZATION
(ONE SHOT)
52
POLYHYDROXY
COMPOUNDS
POLYMERIZATION
(PREPOLYMER SYSTEM)
53
POLYURETHAN
FOAM
TO SALES
PREPOLYMER
TO SALES
LEGEND
○ GASEOUS EMISSIONS
□ SOLID EMISSIONS
△ LIQUID EMISSIONS

FIGURE 19 . POLYURETHAN FOAM PRODUCTION

Phosgenation

1. Function - Phosgenation of primary amines is the commercial method for production of isocyanates. The usual method requires two stages. An amine slurry is treated in a stirred, jacketed kettle with phosgene at a fairly low temperature. The temperature is then raised and more phosgene is added. Distillation provides a means of product purification. The isocyanates formed are then used as a feed to polymerization processes. HCl is obtained as a marketable by-product.

2. Input Materials - Amines such as tolylene diamine and diphenylmethane diamine are the most commonly used. Phosgene is the other reactant required. Requirements for toluene diisocyanate (TDI) are 1.15 Mg (2,530 lb) phosgene and 0.6556 Mg (1,444 lb) toluenediamine per ton of toluenediisocyanate produced.

3. Operating Parameters - The first stage of the phosgenation of toluenediamine takes place at 50° to 70°C. The second stage is at a higher temperature: 120° to 150°C. The reaction time for the second stage is 180 min.

4. Utilities - Utility requirements for producing TDI are listed below in Table 35.

Table 35. UTILITY REQUIREMENTS FOR PRODUCING TOLUENE DIISOCYANATE[a]

cooling water	278 m^3/hr	(73,500 gal/hr)
process water	7.9 m^3/hr	(2,100 gal/hr)
steam	0.73 Mg/hr	(1,600 lb/hr)
power	548 kW	
fuel	51.8 kW	(177,000 Btu/hr)

[a] Based on Mobay and Bayer patents and assuming 131 Mg (288,000 lb)/yr capacity.

5. Waste Streams - A water scrubber is used on the waste gas stream. Scrubbing HCl results in an acid waste stream amounting to 25 g HCl/kg TDI. Polymers and tars from the purification procedures amount to 19.2 g per kg of TDI produced. Although the literature did not include a discussion of the presence of phosgene and aromatic amines in waste streams or in fugitive emissions, the use of these toxic substances presents a potential hazard.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Frey, H. E. Diisocyanates and Polyisocyanates. In: Chemical Economics Handbook. Menlo Park, Ca., Stanford Research Institute, Jan. 1976, p. 666.5021A-666.5022U.

(2) Frey, H. E. Polyurethane Foams. In: Chemical Economics Handbook. Menlo Park, Ca., Stanford Research Inst., Jan. 1976, p. 580.1561A-580.1562T.

(3) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(4) Piggot, K. A. Polyurethanes. In: Encyclopedia of Polymer Science and Technology, Vol 11. H. F. Mark, ed. N.Y., Wiley, 1969, p. 506-63.

(5) Wright, P. and A.P.C. Cumming. Solid Polyurethane Elastomers. New York, Gordon and Breach Science Publishers, 1969.

Polymerization (One Shot)

1. Function - In the one-shot method all of the input materials are combined and polymerization and foaming are completed. An isocyanate, a polyhydroxy compound (polyester or polyether), stabilizers, blowing agents, and catalyst are metered into a continuous mixer. Metering pumps with ±0.5% accuracy are required. They may be gear, piston, or high-pressure fuel injection type. Variable speed drive is also necessary.

Foaming then takes place in forming devices where the foam is formed and set. Slabs are formed on continuous conveyors; more complex shapes are formed in molds. Foam slabs are cut into standard lengths, treated with steam or heat, and transported to curing ovens.

2. Input Materials - Isocyanates commonly used in preparing polyurethan foams are listed in Table 36.

Table 36. ISOCYANATES USED IN POLYURETHAN FOAM PRODUCTION

Chemical Name	Common Name
80/20 2,4-/2,6-Tolylene diisocyanate	80/20 TDI
65/35 2,4/2,6-Tolylene diisocyanate	65/35 TDI
2,4-Tolylene diisocyanate	2,4 TDI
Modified tolylene diisocyanates	crude TDI
4,4'-Diphenylmethane diisocyanate	MDI
Polyisocyanates from aniline-formaldehyde condensates	Undistilled, crude, or polymeric MDI
1,6-Hexamethylene diisocyanate	HDI
4,4'-Dicyclohexylmethane diisocyanate, mixed isomers	———

Polyhydroxy compounds may be polyester polyols, polyether polyols, or naturally occuring compounds. Some of these are polypropylene glycols, propylene oxide adducts of glycerin, and 1,2,6-hexanetriol. There are hundreds of combinations of reactants possible to make a wide variety of polyurethan products.

Catalysts include organic tin compounds used in conjunction with tertiary amines such as tetramethylguanidine; N, N, N', N'-tetramethyl butane diamine; triethylenediamine and dimethylaminoethanol. Surfactants may be used to stabilize the foam. Nonreactive blowing agents and flame retardants may also be used. Flame retardants are usually liquid organic compounds containing chlorine, bromine, and/or phosphorus.

Typical compositions for flexible and rigid foams are listed in Table 37.

Table 37. TYPICAL FORMULATIONS FOR FLEXIBLE AND RIGID FOAMS

	Parts by Weight
Flexible	
polyether polyol, functionality 2-3, hydroxyl number 56	100
water	3.5
silicone copolymer stabilizer	0.1
stannous octoate	0.2
triethylene diamine	0.1
tolylene diisocyanate	45
Rigid	
polyether polyol, functionality 4-8, hydroxyl number 450	100
flame retardant	20
$CFCl_3$ (blowing agent)	35
tertiary amine	2
silicone copolymer stabilizer	1
polymeric MDI-type polyisocyanate	115

3. Operating Parameters - Foam machines have throughputs of 0.9 to 450 kg (2 to 1000 lb)/min. Standard slab sizes are 2 m by 0.6 to 0.9 m and the production rate is usually 45 to 90 kg (100 to 200 lb)/min. Conveyors are from 15 to 30 m (50 to 100 ft) long and travel at rates up to 6 m (20 ft)/min.

4. Utilities - No data were available in the sources consulted for the one-shot process.

5. Waste Streams - The only potential problem posed by this process is in fugitive leaks and spills of isocyanate compounds. These compounds are toxic and irritants and must be removed from work areas.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Backus, John K. Urethanes. In: Chemical and Process Technology Encyclopedia. Douglas M. Considine, ed. N.Y., McGraw-Hill, 1974, p. 1121.

(2) Chemical Technology: An Encyclopedic Treatment, Vol VI, N.Y., Harper & Row, 1973, p. 582.

(3) Environmental Protection Agency, Effluent Guidelines Division. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Polymers Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-75/036-b. Washington, D.C., Jan. 1975.

(4) Frey, H. E. Polyurethane Foams. In: Chemical Economics Handbook. Menlo Park, Ca., Stanford Research Inst., Jan. 1976, p. 580. 1561A-580.1562T

(5) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 292.

(6) Piggot, K. A. Polyurethanes. In: Encyclopedia of Polymer Science and Technology, Vol 11. H. F. Mark, ed. N.Y., Wiley, 1969, p. 506-63.

(7) Wright, P. and A.P.C. Cumming. Solid Polyurethane Elastomers. New York, Gordon and Breach Science Publishers, 1969.

Polymerization (Prepolymer Systems)

1. Function - For some applications it is convenient to make a prepolymer which is crosslinked and foamed later, often at the point of fabrication. This is accomplished by reacting an excess of isocyanate with polyol to form a low molecular weight polymer. Processing is generally by the batch method but may be continuous. In the batch process the reactants are pumped to a stainless steel, jacketed, agitated reactor which has been purged with nitrogen. The reaction proceeds in a nitrogen atmosphere with temperature control provided by steam and cooling water. The continuous process may utilize scraped film heat exchangers instead of kettle reactors. The prepolymer is stored under inert gas for marketing as a two-component system for use by the consumer. The second component may contain more polyol and water as a blowing agent.

2. Input Materials - In prepolymer systems an excess of isocyanate is generally used. A two-step polyurethan prepolymer process is reported to require 0.722 Mg (1590 lb) toluene diisocyanate and 0.19 Mg (410 lb) of polyether per ton of product.

3. Operating Parameters - Reaction temperatures are 46 to 85°C (115 to 185°F) for batch processes and 100 to 120°C (220 to 240°F) for continuous processes.

4. Utilities - Table 38 contains utility requirements for prepolymer manufacture by both batch and continuous processes.

Table 38. UTILITY REQUIREMENTS FOR POLYURETHAN PREPOLYMER PRODUCTION[a]

	Batch[b]	Continuous
steam (kg/hr)	30	34
cooling water (m^3/hr)	5.2	4.5
power (kW)	7.5	28
nitrogen (m^3/hr)	0.61	0.13
dry air (m^3/hr)	0.35	0.40

[a] 4.5 Mg (10,000 lb)/yr capacity

[b] average values

5. Waste Streams - The pollution potential is reported in several references to be very low, even insignificant. The only potential problem lies in the use of toxic isocyanates which may be spilled or lost as fugitive emissions.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Backus, John K. Urethanes. In: Chemical and Process Technology Encyclopedia. Douglas M. Considine, ed. N.Y., McGraw-Hill, 1974, p. 1121-25.

(2) Environmental Protection Agency, Effluent Guidelines Division. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Polymers Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-75/036-b. Washington, D.C., Jan. 1975.

(3) Frey, H. E. Polyurethane Foams. In: Chemical Economics Handbook. Menlo Park, Ca., Stanford Research Inst., Jan. 1976, p. 580.1561A-580.1562T.

(4) Hedley, W. H., et al. Potential Pollutants from Petrochemical Processes, Final Report. Contract 68-02-0226, Task 9, MRC-DA-406. Dayton, Ohio, Monsanto Research Corp. Dayton Lab., Dec. 1973.

(5) Jones, Robert W. and K. T. Chandy. Synthetic Plastics. In: Riegel's Handbook of Industrial Chemistry, 7th Ed. James A. Kent, ed. N.Y., Van Nostrand Reinhold, 1974, p. 292.

(6) Piggot, K. A. Polyurethanes. In: Encyclopedia of Polymer Science and Technology, Vol 11. H. F. Mark, ed. N.Y., Wiley, 1969, p. 506-63.

(7) Wright, P. and A.P.C. Cumming. Solid Polyurethane Elastomers. New York, Gordon Breach Science Publishers, 1969.

POLYAMIDE RESIN PRODUCTION PROCESSES

This operation treats both the reactive and nonreactive polyamides which are chemically based on fatty acids. Although there is a lack of quantitative and definitive information, a general and qualitative description is given. The resins produced in this operation are generally blended with other resin products. These formulating or blending processes are not included here.

Figure 20 is a process flow sheet indicating the processing sequence involved in producing these polyamide resins. Two processes are defined and described in this operation: 54) Dimerization and 55) Condensation.

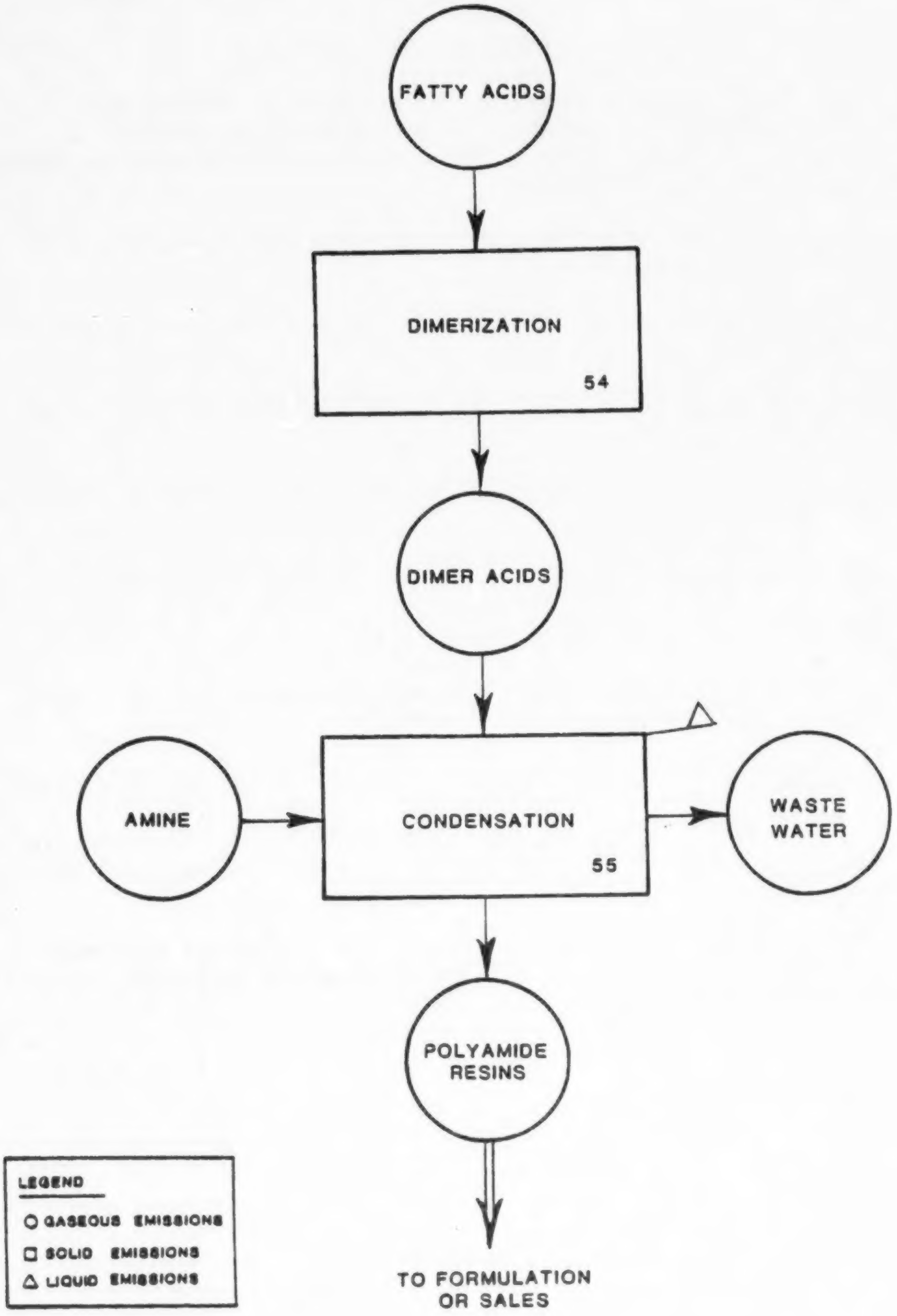

FATTY ACIDS
DIMERIZATION
54
DIMER ACIDS
AMINE
CONDENSATION
55
WASTE WATER
POLYAMIDE RESINS
TO FORMULATION OR SALES
LEGEND
○ GASEOUS EMISSIONS
☐ SOLID EMISSIONS
△ LIQUID EMISSIONS

FIGURE 20. POLYAMIDE RESIN PRODUCTION

Dimerization

1. Function - Very little information is available concerning this process. Mono-basic acids undergo cycloaddition to form a blend of monomers and polymers containing predominantly dimer. The unreacted monomer must be removed before the polyamides can be produced.

2. Input Materials - Fatty acids such as linoleic and ricinoleic acids are input materials to this process.

3. Operating Parameters - Data were not available in the literature consulted for this study.

4. Utilities - Data were not available in the literature consulted for this study.

5. Waste Streams - Lack of information on this process precludes discussion of potential emissions.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Chemical Technology: An Encyclopedic Treatment, Vol VI. N.Y., Harper & Row, 1973, p. 576.

(2) Floyd, Don E. Polyamide Resins. 2nd Ed. N.Y., Reinhold, 1966.

(3) Peerman, D. E. Polyamides from Fatty Acids. In: Encyclopedia of Polymer Science and Technology, Vol 10. H. F. Mark, ed. N.Y., Wiley, 1969, p. 597-615.

(4) Wallace, Peter T. Polyamide Resins. In: Chemical Economics Handbook. Menlo Park, Ca., Stanford Research Institute, March 1974, p. 580.1031A-580.1032E.

POLYAMIDE RESIN PRODUCTION

PROCESS NO. 55

Condensation

1. Function - The dimer acid product and an amine are charged to an agitated autoclave reactor. As the temperature is increased the reaction begins, and water of reaction is formed and distilled off continuously. A vacuum may be applied to force the reaction to completion. The vacuum is released with inert gas, and the resin is discharged.

2. Input Materials - The dimer acid charged to the reactor is a blend of compounds containing 60 to 75 percent dimer, 5 to 20 percent trimer and higher homologs, and the remainder unextracted monomer.

The amine feed for nonreactive polyamides is a difunctional amine; ethylene diamine is generally used. Reactive polyamide resins require polyfunctional amine feeds. Diethylenetriamine is most commonly used; triethylenetetramine and tetraethylenepentamine are also used.

3. Operating Parameters - Reaction temperature is 150 to 250°C.

4. Utilities - Data were not available in the sources consulted for this study.

5. Waste Streams - The water of reaction forms a liquid waste stream. No accounts of the disposition of this waste were evident in the literature consulted for this study.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02

7. References -

(1) Chemical Technology; An Encyclopedic Treatment, Vol VI. N.Y., Harper & Row, 1973, p. 576.

(2) Floyd, Don E. Polyamide Resins. 2nd Ed. N.Y., Reinhold, 1966.

(3) Peerman, D. E. Polyamides from Fatty Acids. In: Encyclopedia of Polymer Science and Technology, Vol 10. H. F. Mark, ed. N.Y., Wiley, 1969, p. 597-615.

(4) Wallace, Peter T. Polyamide Resins. In: Chemical Economics Handbook. Menlo Park, Ca., Stanford Research Institute, March 1974, p. 580.1031A-580.1032E.

POLY(PHENYLENE SULFIDE) PRODUCTION PROCESSES

Poly(phenylene sulfide) is characterized by a rigid backbone chain of recurring para-substituted benzene rings and sulfur atoms. Processing information was available in only one of the sources consulted for this study. That information, although somewhat sketchy is presented here in two processes: 1). Polymerization and 2). Product Preparation. Figure 21 is a flowsheet indicating the flow of materials in this operation, including waste streams.

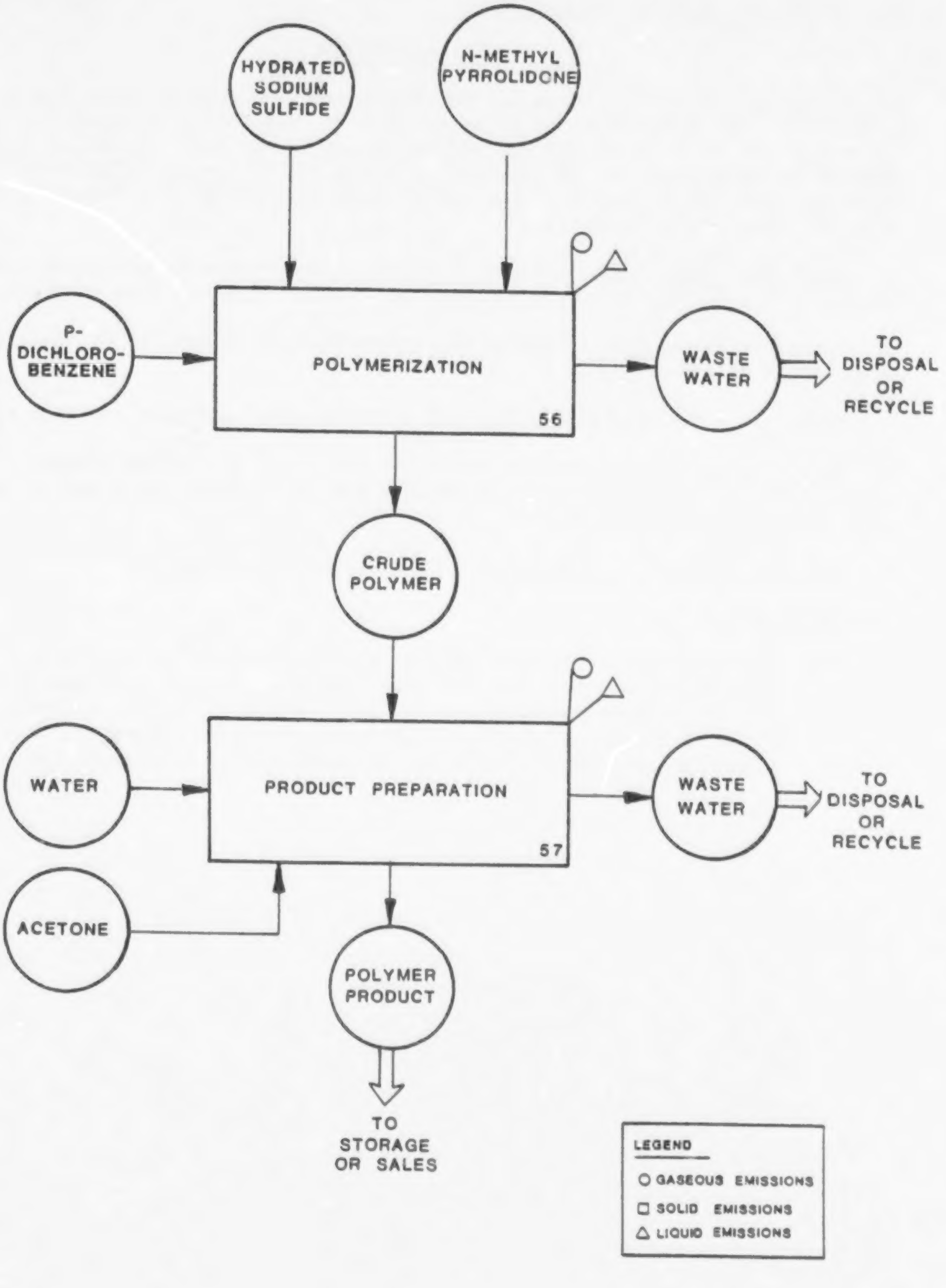

HYDRATED SODIUM SULFIDE
N-METHYL PYRROLIDONE
P-DICHLOROBENZENE
POLYMERIZATION
56
WASTE WATER
TO DISPOSAL OR RECYCLE
CRUDE POLYMER
WATER
PRODUCT PREPARATION
57
WASTE WATER
TO DISPOSAL OR RECYCLE
ACETONE
POLYMER PRODUCT
TO STORAGE OR SALES
LEGEND
○ GASEOUS EMISSIONS
□ SOLID EMISSIONS
△ LIQUID EMISSIONS

FIGURE 21. POLY(PHENYLENE SULFIDE) PRODUCTION

Polymerization

1. Function - Hydrated sodium sulfide and N-methyl-pyrrolidone are charged to a reactor. The temperature is elevated, and the reactor is flushed with nitrogen to remove the water of hydration. After the water has been removed, p-dichlorobenzene is added, and the temperature is increased to the reaction temperature. When the reaction is complete, the contents of the reactor are dropped into a tank for washing in Process No. 57.

2. Input Materials - The mole ratio of p-dichlorobenzene to sodium sulfide should be 0.9-1.3:1. Nitrogen and N-methyl pyrrolidone are also required.

3. Operating Parameters - Dehydration temperature is about 190°C; reaction temperature is about 250°C.

4. Utilities - No data were available in the source consulted for this study.

5. Waste Streams - The water of hydration forms a liquid waste stream. This aqueous stream is likely contaminated with sodium sulfide, and N-methyl pyrrolidone may also be encountered.

6. EPA Source Classification Code - Polyprod General 3-01-018-02.

7. References -

(1) Environmental Protection Agency, Effluent Guidelines Division. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Polymers Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-75/036-b. Washington, D.C., January, 1975.

Product Preparation

1. Function - The reactor contents are washed with water to remove sodium chloride and then with acetone to remove unreacted input materials. The polymer is then dried and packaged.

2. Input Materials - 10,000 kg of wash water are required per 1000 kg of product resin. Acetone is required in unknown quantities. It is expected that recovery and recycle methods are used when possible, making requirements lower.

3. Operating Parameters - No data were given in the source consulted for this study.

4. Utilities - No data were given in the source consulted for this study.

5. Waste Streams - Wash water and acetone containing sodium chloride, sodium sulfide, and N-methyl pyrrolidone form a liquid waste stream from this process. Some raw materials may be recovered for recycle. No mention was found regarding the disposition of this waste.

It is assumed that particulate and gaseous emissions result from drying, but no information on the drying technique was found.

6. EPA Source Classification Code - Polyprod General 3-01-018-02.

7. References -

(1) Environmental Protection Agency, Effluent Guidelines Division. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Polymers Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-75/036-6. Washington, D.C., January, 1975.

POLYACETAL PRODUCTION PROCESSES

Acetal resins are produced by addition of aldehyde molecules through the C=O group. This definition specifically excludes those polymers produced by the aldol condensation. Because of their commercial significance, only polymers derived from formaldehyde will be dealt with in this discussion. Homopolymers and copolymers are produced, differing in the occurence of a C-C bond in the copolymer. Stabilization of the hemiacetal end groups is a common practice.

The description of the acetal resins manufacture which follows may appear superficial. Sources available gave evidence of probable waste streams but were seriously deficient in definitive data concerning processing. What follows is an interpretation and analysis of a rather vague description of the production of acetal resins.

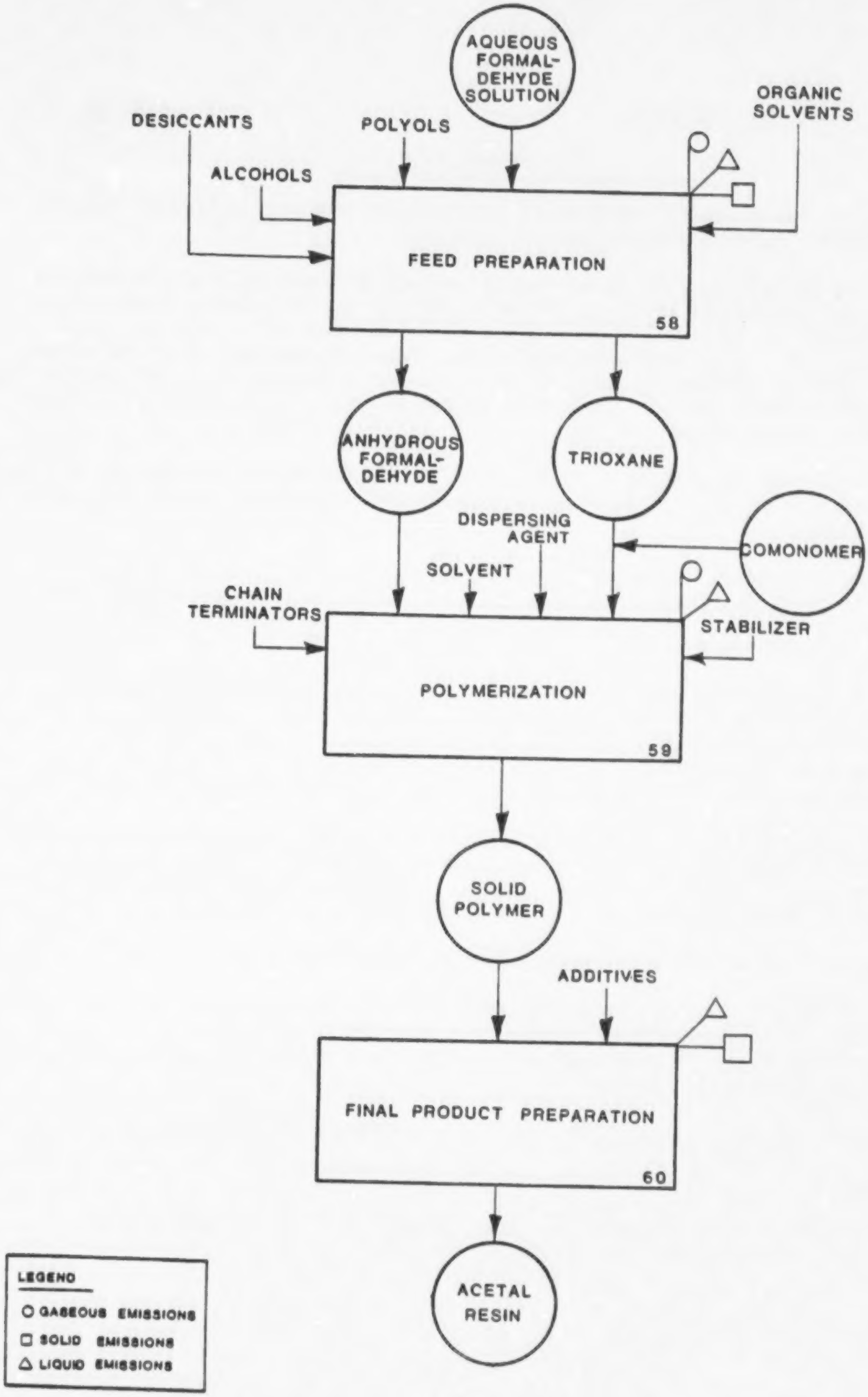

AQUEOUS FORMAL- DEHYDE SOLUTION
DESICCANTS
POLYOLS
ORGANIC SOLVENTS
ALCOHOLS
FEED PREPARATION
58
ANHYDROUS FORMAL- DEHYDE
TRIOXANE
DISPERSING AGENT
SOLVENT
COMONOMER
CHAIN TERMINATORS
STABILIZER
POLYMERIZATION
59
SOLID POLYMER
ADDITIVES
FINAL PRODUCT PREPARATION
60
ACETAL RESIN
LEGEND
○ GASEOUS EMISSIONS
☐ SOLID EMISSIONS
△ LIQUID EMISSIONS

FIGURE 22. POLYACETAL PRODUCTION

Feed Preparation

1. Function - The formaldehyde feed is provided for the polymerization process in the form of anhydrous formaldehyde or trioxane.

Anhydrous formaldehyde is furnished by thermal decomposition of a purified prepolymer or hemi-formal which is thermally decomposed to release formaldehyde. Paraformaldehyde is formed by evaporation and dessication of an aqueous formaldehyde solution. α-polyoxymethylene may be formed by heating paraformaldehyde or by treatment of an aqueous formaldehyde solution with catalysts and dehydrating agents. Hemi-formals are synthesized by adding alcohols (commonly cyclohexanol) to an aqueous formaldehyde solution.

Impurities such as methanol, formic acid, and water may be removed by washing with non-volatile polyols or by freeze-trapping slightly above the boiling point of formaldehyde.

Trioxane is prepared by acidification and distillation from an aqueous formaldehyde solution. The trimer may then be separated from the aqueous distillate by extraction or crystallization before it is further purified by fractional distillation.

2. Input Materials - An aqueous formaldehyde solution is the major feedstock to this process. Preparation of prepolymers and hemiformals for provision of anhydrous formaldehyde may require dehydrating agents, alcohols, and non-volatile polyals for washing. Trioxane preparation may utilize solvents such as methylene chloride, trichloronaphthalene, and trichlorobenzene for extraction.

3. Operating Parameters - Thermal decomposition of the formaldehyde polymers and the hemi-formals is usually accomplished at 130-165°C. The boiling point of formaldehyde is -15°C. Trioxane is distilled from a 60-65% aqueous formaldehyde solution; trioxane boils at 114.3°C at atmospheric pressure.

4. Utilities - None available in the sources consulted for this study.

5. Waste Streams - Although waste streams were not defined in the sources consulted for this study, an aqueous waste stream is assumed from distillation and dehydration of the aqueous formaldehyde solution. Fugitive gaseous emissions of formaldehyde are also assumed.

6. EPA Source Classification Code - Polyprod. General 3-01-018-02.

7. References -

(1) Barker, S. J., and M. B. Price. Polyacetals. American Elsevier Publishing Company, Inc. New York, 1971.

(2) Environmental Protection Agency, (Office of Air and Water Programs, Effluent Guidelines Div.). Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(3) Bevington, J. C., and H. May. Aldehyde Polymers. Encyclopedia of Polymer Science and Technology. Volume 1, H. F. Mark, ed., N.Y., Wiley, 1964, p. 609-628.

Polymerization

1. Function - In forming a polymer product from anhydrous formaldehyde the monomer is added to an agitated inert diluent containing intiators and dispersants maintained at a low temperature. Molecular weight control is accomplished through the addition of chain-termination and transfer agents. The reaction is stopped by shutting off the flow of monomer. The solid polymer is separated from the diluent by filtration or centrifugation.

End-stabilization, accomplished by acetylation is done by mixing with acetic anhydride and refluxing. The product is then washed and dried.

Trioxane may be polymerized by bulk, suspension, or solution methods (see processes 1-8). Stabilization is accomplished by copolymerization with cyclic ethers.

2. Input Materials - Anhydrous formaldehyde or trioxane are the monomer materials used in this process. Solvents for polymerization of anhydrous formaldehyde include propane, cyclohexane, and aromatics. Indicated dispersing agents are etherified polyethylene glycols. Chain termination and transfer agents include water, methanol, formic acid, acetic anhydride, and ethylacetate. Acetic anhydride is used in the ratio of 10 volumes per volume of dry polymer.

Indicated solvents for solution polymerization are cyclohexane, benzene, nitrobenzene, methylene dichloride, and ethylene dichloride. Comonomers used are oxacyclic compounds such as 1,3-dioxolane, 1,4-dioxolane, ethylene oxide, and tetrahydrofuran.

3. Operating Parameters - Catalysts for formaldehyde polymerization include amines, phosphines, arsines, stibines, metal carbonyls, onium compounds, and metallorganic compounds. Sodium acetate is used as a catalyst for acetylation with acetic anhydride. Reflux time is 30 minutes.

Catalysts for trioxane polymerization are boron trifuloride etherates, aryldiazonium fluoroborates, antimony trifluoride, iodine, Friedel-Crafts catalysts, perchloric acid, and acetyl perchlorate.

4. Utilites - None specified in the sources consulted for this study.

5. Waste Streams - Wastes from mass addition, suspension, and solution polymerization are discussed in processes 1-8. Fugitive gaseous emissions of formaldehyde and organic solvents are probable.

6. EPA Source Classification Code - Polyprod General 3-01-018-02.

7. References -

(1) Barker, S. J., and M. B. Price. Polyacetals. American Elsevier Publishing Company, Inc. New York, 1971.

(2) Environmental Protection Agency, (Office of Air and Water Programs. Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(3) Bevington, J. C., and H. May. Aldehyde Polymers. Encyclopedia of Polymer Science and Technology. Volume 1. H. F. Mark, ed., New York, Wiley, 1964, p-609-628.

Final Product Preparation

1. Function - Blending of additives with the polymer may be accomplished in an extruder. Extruded molten strands are then quenched directly in a water bath before pelletizing and storing.

2. Input Materials - Solid polymer from Process No.59 is blended with antioxidants, stabilizers, and acid acceptors.

3. Operating Parameters - None available in the sources consulted for this study.

4. Utilities - None available in the sources consulted for this study.

5. Waste Streams - Particulates may be emitted from pelletizing and bagging procedures. This source also has the potential for creating a solid waste stream from spills in materials handling. Pneumatic conveyor systems may cause additional particulate emissions. A purge stream of quench water containing polymer fines is commonly discarded as waste from water quenching operations.

6. EPA Source Classification Code - Polyprod. General 3-018-01-02.

7. References -

(1) Barker, S. J. , and M. B. Price. Polyacetals. American Elsevier Publishing Company, Inc. New York, 1971.

(2) Environmental Protection Agency, (Office of Air and Water Programs. Effluent Guidelines Div.) Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Synthetic Resins Segment of the Plastics and Synthetic Materials Manufacturing Point Source Category. EPA 440/1-74-010-a. Washington, D. C., 1974.

(3) Bevington, J. C., and H. May. Aldehyde Polymers. Encyclopedia of Polymer Science and Technology. Volume 1. H. F. Mark, ed., New York, Wiley, 1964, p.609-628.

APPENDIX A

RAW MATERIALS

Table A-1. RAW MATERIALS LIST

Monomers and Initial Inputs
Styrene
Acrylonitrile
Butadiene
Vinyl chloride
Alkyl acrylates (e.g. methyl acrylate)
Allyl esters of aromatic acids
Vinylidene chloride
Tetrafluoroethylene
Trifluorochloroethylene (Chlorotrifluoro ethylene)
Vinyl acetate
Alkyl methacrylates (e.g., methyl methacrylate)
Chloroprene
Isoprene
α-Methylstyrene
Isobutylene
Methacrylic acid esters
Acrylic acid esters
Divinyl benzene
Ethylene
Acrylic acid
Methacrylic acid
Acrylamide
N-vinyl-2-pyrrolidone
Polymerizable vinyl comonomers
2, 2, 4-Trimethylpentane
Phenol
Formaldehyde (or solid poraformaldehyde)
Hexamethylene diamine adipate
Alcohols (e.g., methanol, ethanol, butanol, octanol)
Hexamethylenediamine
Hexamethylenetetramine
Bases (e.g., calcium hydroxide, sodium hydroxide, lime)

Table A-1 (Continued). RAW MATERIALS LIST

Monomers and Initial Inputs
Acids (H_2SO_4, HCl, HAc)
Nitrogen-containing compounds (e.g., urea, melamine, amino acids)
Bisphenol-A
Phosgene
Pyridine
Epichlorohydrin
Polyphenols
Polyalcohols
Unsaturated dibasic acids (e.g., phthalic acid, maleic acid, fumaric acid-(usually in form of anhydrides) (e.g., dodecanoic acid, pelargonic acid)
Aromatic dibasic acids (isophthalic acid, adipic acid, azelaic acid)
Dihydric alcohols (e.g. ethylene glycol, diethylene glycol, propylene glycol, polypropylene glycol, dipropylene glycol, neopentyl glycol)
Vinyl toluene
Polyhydric alcohols (e.g., pentaerythritol, glycerol, dipentaerythritol, trimethylolethane, sorbitol)
Polybasic acids (adipic acid, sebacic acid)
Fatty acids (soya oil, safflower oil, castor oil, linseed oil, coconut oil, cottonseed fatty acids, tall oil fatty acids, linoleic acid, ricinoleic acid)
Terephthalic acid
Dimethyl terephthalate
Lactams (e.g., caprolactam, 11-aminoundecanoic acid, lauryllactam)
Toluene
Tolylene diamine
Diphenylmethane diamine
Polyester polyols
Polyether polyols
Polyfunctional amines (e.g., diethylene triamine, tetraethylene tetramine, tetraethylene pentamine)
Propylene oxide adducts of glycerin and 1, 2, 6-hexanetriol
Tolylenediisocyanate

Table A-1 (Continued). RAW MATERIALS LIST

Stabilizers and buffering agents
Casein
Glue
Tragacanth gum
Albumin
Starch
Methyl cellulose
Polyvinyl alcohol
Phosphates
Carbonates
Salts of styrene-maleic anhydride copolymers
Vinylacetate-maleic anhydride copolymers and salts
Gelatin
Methanol
Surfactants
Silicone copolymer

Table A-1 (Continued). RAW MATERIALS LIST

Initiators

- Water-soluble peroxidic compounds
  - hydrogen peroxide
  - urea peroxide
  - potassium persulfate
  - sodium perborate
  - ammonium peroxysulfate
  - cumene hydroperoxide
- Monomer-soluble catalysts
  - benzoyl peroxide
  - diacyl peroxides
  - lauroyl peroxide
  - diisopropyl peroxy dicarbonate
  - t-butyl peroxy pivalate
- Air, oxygen
- Sodium hydroxide
- Calcium hydroxide

Table A-1 (Continued). RAW MATERIALS LIST

Catalysts
Water-soluble inorganic reducing agents (commonly chelated iron)
Benzoyl peroxide
Lauroyl peroxide
Azobis isobutyronitrile
Hydrogen peroxide
Ammonia
Hexavalent chromium oxide on silica-alumina
Metal alkyl compounds (ethyl and isobutyl aluminum hydride and chlorides, trialkyl aluminum compounds)
Alkylhalides
Titanium trichloride
Metal salts (litharge, lithium compounds)
Oxides, carbonates, and acetates of zinc, calcium, manganese, magnesium, cobalt, antimony
Organic tin compounds (stannous octoate)
Tertiary amines
tetramethylguanidine
N, N, N', N'-tetramethyl butane diamine
Triethylene diamine
Dimethyl aminoethanol

Table A-1 (Continued). RAW MATERIALS LIST

Modifiers, or chain-transfer agents
Mercaptans
Halogenated aliphatic hydrocarbons
Hydrocarbons with active hydrogens (cumene)
Ketones
Aldehydes
Alkanes
Olefins
Alcohols
Chlorinated compounds
Hydrogen
Alkyl-zinc compounds

Table A-1 (Continued). RAW MATERIALS LIST

Solvents
Water
Hydrocarbon solvents
Ethylbenzene
Alcohol (ethanol, butanol)
Benzene
Toluene
Pentane
Cyclohexane
Cellosolve acetate
Methyl ethyl ketone
Cyclohexanone
Ethylene chloride
Chlorobenzene
Ketones
Xylene

Table A-1 (Continued). RAW MATERIALS LIST

Emulsifiers
Soaps of long-chain alcohols
Potassium dihydroabietate
Potassium caprylate
Potassium caprate
Potassium laurate
Potassium myristate
Potassium palmitate
Potassium stearate
Potassium oleate
Sodium oleate
Sodium rosenate
Salts of aliphatic and aromatic sulfonic acids
Sodium decylsulfonate
Sodium tetradecyl sulfonate
Sodium decyl sulfate
Sodium dodecyl sulfate
Aliphatic amines and their salts (salts of amines, quaternary ammonium salts of long-chain cylic amines)
Ammonium or amino soaps
Non-ionic emulsifiers
Polyalcohols
Polyesters
Alkyl sulfates
Alkyl sulfonates

Table A-1 (Continued). RAW MATERIALS LIST

Suspension Agents
(tri) calcium phosphate (hydroxy apatite)
Barium sulfate
Aluminum hydroxide
Bentonite clay
Calcium oxalate
Gelatin
Poly(vinyl pyrrolidone)
Poly(vinyl alcohol)
Carboxymethyl cellulose
Hydroxyethyl cellulose
Polyacrylic acid
Polymethacrylic acid
Acrylic-methacrylic acid
Ester copolymers

Table A-1 (Continued). RAW MATERIALS LIST

Other Additives
Colorants, pigments, toners
Plasticizers (See Synthetic Plasticizers)
Flocculating agents
Carbon (adsorbent)
Release agents, lubricants
Breaking agents
Precipitants (aliphatic hydrocarbons)
Optical Brighteners
Blowing agents (e.g., $CFCl_3$)
Oxidizers (e.g., potassium permanganate)
Flame retardants (e.g., liquid organic compounds containing chlorine, bromine, and/or phosphorus)
Delustrants (e.g., titanium dioxide, uranyl phosphites or phosphates, phenol compound)
Oxygen scavengers (e.g., sodium dithionate)
Inhibitors, short-stops, chain terminators (e.g. hydroquinone, p-tert-butyl catechol, phenolic resins, aromatic amines, pyrogallol, chloranil, picric acid, HAc)
Fillers (e.g., alpha cellulose, wood flour, asbestos)
Curing agents (e.g., amines; polyamides; acids; acid anhydrides; phenolic, urea, and melamine resins; benzolyl peroxide; methylethyl ketone peroxide; di-t butyl peroxide, dicumyl peroxide)

TABLE A-2 thru A-7 deleted:

SOURCE: The October 1974 issue of Modern Plastics Encyclopedia. Copyrighted 1974 by McGraw-Hill., 1221 Avenue of the Americas, New York, N.Y. 10020

APPENDIX B
PRODUCTS

Table B-1. PRODUCTS OF THE PLASTICS AND RESINS INDUSTRY

Acetal resins
Acetone-formaldehyde resins
Acrylamide resin
Acrylamide-acrylic acid copolymer
Acrylic resins
   (includes acrylic emulsion polymers, acrylic latex)
Acrylonitrile-butadiene styrene resin (ABS)
Adipic acid-tetraethylene pentamine paper resin
Alkyd resins (phthalic acid resins)
   (includes alkyl molding compounds)
Alkylphenol-acetylene resins
Aniline-formaldehyde resins
Butylphenol-formaldehyde resins
Cellophane
Cellulose resins
Coumarone-indene resins (coal tar resins) (petroleum resins)
Cresol-formaldehyde resins (unmodified)
Cresylic-acid-formaldehyde resins (unmodified)
Diallyl phthalate resins
Dicyandiamide resins
Dimethyl hydantoin-formaldehyde resins
Epoxy resins
   modified
   unmodified
Ethylene-maleic anhydride copolymer resins (EMA resins)
Ethylene-vinyl acetate copolymer resins (vinyl acetate-ethylene copolymers)
Fluorocarbon resins (polyfluoro ethylene resins)
Furan resins (Furfuryl alcohol resins)
Glyoxal-formaldehyde resins
Hydrocarbon resins (coal tar resins) (petroleum resins)
Ionomer resins (Surlyn®)
Ketone-aldehyde resins
Maleic resins

Table B-1 (Continued). PRODUCTS OF THE PLASTICS AND RESINS INDUSTRY

- Melamine-formaldehyde resins (Amino resins)
- Methyl vinyl ether - maleic anhydride copolymer resin (Gantrez®)
- Methyl vinyl ether - mono butyl maleate copolymer resin
- Methyl vinyl ether - mono ethyl maleate copolymer resin
- Methyl vinyl ether polymer resin
- Phenol-formaldehyde resins
- Phenol-resorcinal-formaldehyde resins
- Plastisols
- Polyamide resins (Nylon resins)
- Polybutene-1 resins (polybutylene)
- Polybutylene terephthalate
- Polycarbonate resins
- Poly (1,4-cyclo hexylene dimethylene terephthalalate/isophthalate) copolymer
- Polyester resins
  - saturated (excludes resins for polyester fibers)
  - unsaturated (includes alkyd molding compounds)
- Polyethylene resins (polyolefin resins)
  - high density
  - low density
- Polyimide resins
  - (includes polyimide, poly(ester-imide), and polyamide-imide types)
- Polyphenylene oxide resins (PPO) (Polydimethyl o-phenyl)
- Polyphenylene sulfide resins
- Polypropylene resins (polyolefin resins)
- Polystyrene resins
  - (straight and rubber-modified - may include certain styrene copolymer resins and elastomers)
- Polysulfone resins
- Polyterpene resins (terpene phenol resins)
- Poly(tetramethylene terephthalate)
- Polyurethane foam
- Polyurethane resins (miscellaneous)
  - (includes adhesives, molding resins, sealants, etc.)
- Polyurethane surface coating resins
- Polyvinyl acetate resins
- Polyvinyl alcohol resins

Table B-1 (Continued). PRODUCTS OF THE PLASTICS AND RESIN INDUSTRY

Polyvinyl butyral resins
Polyvinyl chloride resins
Polyvinyl chloride-acetate copolymer resins
Polyvinyl chloride-propylene copolymer resins
Polyvinyl chloride-vinylidene chloride copolymer resins
Polyvinyl formal resins
Polypropylene-ethylene copolymer resins
Resorcinol-formaldehyde resins
Rosin and rosin ester
Silicone resins
Styrene-allyl alcohol resins
Styrene-acrylonitrile copolymer resins (SAN resins)
Styrene-butadiene copolymer resins
  latex
  resin
Styrene-divinyl benzene copolymer resins
Styrene-maleic anhydride copolymer resins
Thermoplastic resins
Triazone resins
Urea-formaldehyde resins (Ammo resins)
Vinyl 1,2-Polybutadiene resins
1-Vinyl-2-Pyrrolidinone-styrene copolymer resin
Vinyl toluene-acrylic copolymer resin
Vinyl toluene copolymer resin

APPENDIX C

COMPANIES AND PRODUCTS

Table C-1. ACETAL RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Celanese Corp. Celanese Plastics Co., div.	Bishop, TX	48 (105)
E. I. du Pont de Nemours & Co., Inc. Plastics Products and Resins Dept.	Parkersburg, WV	729 (765)

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs. annually.

Source: Directory of Chemical Producers, 1976.

Table C-2. ACETONE-FORMALDEHYDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Reichhold Chems., Inc.	Andover, MA Detroit, MI	
Union Carbide Corp. Chems. and Plastics Div.	Bound Brook, N.J.	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs. annually.

Source: Directory of Chemical Producers, 1976.

Table C-3. ACRYLAMIDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
American Cyanamid Co. Indust. Chems. and Plastics Div.		
	Longview, WA[3]	
	Mobile, AL	
	Springhill, LA	
	Wallingford, CT	
	Kalamazoo, MI[4]	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs. annually

[3] An expansion of acrylamide resins capacity to 90 million pounds per year is planned for completion in 1976

[4] A new acrylamide resins plant has come onstream since January 1, 1976

Source: Directory of Chemical Producers, 1976.

Table C-4. ACRYLIC RESIN PRODUCERS[2]
(Includes acrylic emulsion polymers, acrylic latex)

Company	Location	Capacity[1] Gg(10^6 lbs)
ADCO Chem. Co. Inc.	Newark, NJ	
Alco Standard Corp. Alco Chem. Corp, div.	Philadelphia, PA	
American Aniline & Extract Co., Inc.	Calvert City, KY	
American Cyanamid Co. Indust. Chems. and Plastics Div.	Azusa, CA	
	New Orleans, LA	
	Wallingford, CT	
Anderson Dev. Co.	Adrian, MI	
Ashland Oil, Inc. Lehigh Valley Chem. Co., div. Resins & Plastics Div.	Calumet City, IL	
	Fords, NJ	
	Los Angeles, CA	
	Newark, NJ	
AZS Corp. AZS Chem. Co. Div.	Atlanta, GA	
BASF Wyandotte Corp. Colors and Chems. Group	Kearny, NJ	
Beatrice Foods Co. Beatrice Chem. Div. Polyvinyl Chem. Indust., Div.	Wilmington, MA	
Borden Inc. Borden Chem. Div. Thermoplastic Products	Bainbridge, NY	
	Compton, CA	
	Demopolis, AL	
	Illiopolis, IL	
	Leominster, MA	

Table C-4 (Continued). ACRYLIC RESIN PRODUCERS[2]
(Includes acrylic emulsion polymers, acrylic latex)

Company	Location	Capacity[1] Gg(10^6 lbs)
Celanese Corp.		
Celanese Coatings & Specialty Chems. Co. subsid.		
Celanese Resins Div.	Belvidere, NJ	
	Charlotte, NC	
	Los Angeles, CA	
	Louisville, KY	
	Newark, CA	
Wica Chems. Div.	Charlotte, NC	
Chem. Processors, Inc.	Seattle, WA	
Chem. Products Corp.	Elmwood Park, NJ	
Cook Paint & Varnish Co.	Detroit, MI	
	Houston, TX	
	Milpitas, CA	
	North Kansas City, MO	
De Soto, Inc.	Berkeley, CA	
	Chicago Heights, IL	
	Garland, TX	
The Dexter Corp.		
Midland Div.	Cleveland, OH	
	Hayward, CA	
	Rocky Hill, CT	
	Waukegan, IL	
Dock Resins Corp.	Linden, NJ	
E. I. du Pont de Nemours & Co., Inc.		
Biochems. Dept.	Belle, WV	
Fabrics and Finishes Dept.	Chicago, IL	
	Flint, MI	
	Parlin, NJ	
	Philadelphia, PA	
	South San Francisco, CA	

Table C-4 (Continued). ACRYLIC RESIN PRODUCERS[2]
(Includes acrylic emulsion polymers, acrylic latex)

Company	Location	Capacity[1] Gg(10^6 lbs)
E. I. du Pont de Nemours & Co., Inc. (Continued) Plastics Products and Resins Dept.	Parkersburg, WV[3]	
ELT Inc. Baltimore Paint and Chem. Corp., subsid.	Baltimore, Md.	
H. B. Fuller Co. Polymer Div.	Atlanta, GA Blue Ash, OH	
Gen. Latex and Chem. Corp.	Ashland, OH Cambridge, MA Charlotte, NC Dalton, GA	
Gen. Mills, Inc. Gen. Mills Chems., Inc., subsid. Indust. Chems. Operations	Kankakee, IL	
The B. F. Goodrich Co. B. F. Goodrich Chem. Co., div.	Avon Lake, OH	
Guardsman Chems., Inc.	Grand Rapids, MI	
Hanna Chem. Coatings Corp.	Columbus, OH	
Hanna Chem. Coatings Co., subsid.	Birmingham, AL	
Hart Products Corp.	Jersey City, NJ	
Hercules Inc. Organics Dept.	Clairton, PA	
E. F. Houghton & Co.	Carrollton, GA Philadelphia, PA	
Hugh J.-Resins Co.	Long Beach, CA	
Inmont Corp.	Anaheim, CA Detroit, MI	

Table C-4 (Continued). ACRYLIC RESIN PRODUCERS[2]
(Includes acrylic emulsion polymers, acrylic latex)

Company	Location	Capacity[1] Gg(10^6 lbs)
S. C. Johnson & Son, Inc.	Racine, WI	
Kewanee Indust., Inc. Millmaster Onyx Corp., subsid. Refined-Onyx Div.	Lyndhurst, NJ	
Marcor Inc. Montgomery Ward & Co., subsid. Standard T Chem. Co., Inc., subsid.	Staten Island, NY	
Minnesota Mining and Mfg. Co. Chem. Resources Div.	St. Paul, MN	
Mobay Chem. Corp. Verona Dyestuffs Div.	Bayonne, NJ	
Mobil Oil Corp. Mobil Chem. Co., div. Chem. Coatings Div.	Pittsburgh, PA	
Morris Indus. Inc. Lanson Chem. Co., div.	East St. Louis, IL	
Morton-Norwich Products, Inc. Morton Chem. Co., div.	Ringwood, IL	
National Starch and Chem. Corp.	Meredosia, IL	
N L Indust., Inc. Indust. Chems. Div.	Philadelphia, PA	
Norris Paint & Varnish Co.	Salem, OR	
Northeastern Labs, Co., Inc.	Melville, NY	
Nyanza, Inc. Hamilton Chem. Div.	Ashland, MA	
The O'Brien Corp. Fuller-O'Brien Corp., subsid.	South Bend, IN South San Francisco, CA	

Table C-4 (Continued). ACRYLIC RESIN PRODUCERS[2]
(Includes acrylic emulsion polymers, acrylic latex)

Company	Location	Capacity[1] Gg(10^6 lbs)
Onyx Oils & Resins, Inc.	Brooker, FL Newark, NJ	
Philip Morris, Inc. Polymer Indust., Inc., subsid. Adhesives and Liquid Coatings Div.	Springdale, CT	
Textile Chems. Div.	Greenville, SC	
PPG Indust., Inc. Coatings and Resins Div.	Circleville, OH Cheswold, DE[3] Oak Creek, WI	
Purex Corp.	Carson, CA	
K. J. Quinn & Co., Inc. Polymer Div.	Malden, MA Seabrook, NH	
Raffi and Swanson, Inc. Polymeric Resins Div.	Wilmington, MA	
Reichhold Chems., Inc.	Azusa, CA Detroit, MI Elizabeth, NJ South San Francisco, CA	
Reichhold Chem. Del Caribe, Inc., subsid.	Rio Piedras, PR	
H. H. Robertson Co. Freeman Chem. Corp., subsid.	Chatham, VA Saukville, WI	
Rohm and Haas Co.	Bristol, PA Croydon, PA	
Rohm and Haas California Inc., subsid.	Hayward, CA	
Rohm and Haas Kentucky Inc., subsid.	Louisville, KY	
Rohm and Haas Tennessee Inc., subsid.	Knoxville, TN	
Rohm and Haas Texas Inc., subsid.	Deer Park, TX	

Table C-4 (Continued). ACRYLIC RESIN PRODUCERS[2]
(Includes acrylic emulsion polymers, acrylic latex)

Company	Location	Capacity[1] Gg(10^6 lbs)
SCM Corp.		
Glidden-Durkee Div.		
Coatings and Resins Group	Chicago, IL Cleveland, OH Huron, OH Reading, PA San Francisco, CA	
The Sherwin-Williams Co.	Chicago, IL Cleveland, Ohio	
A. E. Staley Mfg. Co.		
Staley Chem. Div.	Kearny, NJ Lemont, IL	
Standard Brands, Inc.		
Standard Brands Chem. Indust., Inc., div.		
Tylac Chems., div.	Cheswold, DE	
The Standard Oil Co. (Ohio)		
Vistron Corp., subsid.		
Chems. Dept.		
Barex® 210 Resin Div.	Cleveland, OH	
Sun Chem. Corp.		
Chems. Group		
Chems. Div.	Chester, SC	
Sybron Corp.		
Ionac Chem. Co., Div.	Birmingham, NJ	
Jersey State Chem. Co., div.	Haledon, NJ	
Kerr Mfg. Co., div.	Romulus, MI	
Syncon Resins Inc.		
Farnow, Inc., div.	South Kearny, NJ	
T. F. Washburn Co., div.	Chicago, IL	
Union Carbide Corp.		
Chems. and Plastics Div.	Bound Brook, NJ Institute and South Charleston, WV	

Table C-4 (Continued). ACRYLIC RESIN PRODUCERS[2]
(Includes acrylic emulsion ploymers, acrylic latex)

Company	Location	Capacity[1] Gg(10^6 lbs)
United Merchants & Mfgs., Inc. Valchem - Chem. Div.	Langley, SC	
USM Corp. Crown-Metro, Inc., subsid.	Greenville, SC	
Yenkin-Majestic Paint Corp. Ohio Polychemicals Co., div.	Columbus, OH	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs. annually

[3] A new acrylic resins plant is planned.

Source: Directory of Chemical Producers, 1976.

Table C-5. ACRYLONITRILE•BUTADIENE•STYRENE RESIN AND STYRENE•ACRYLONITRILE COPOLYMER RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Borg-Warner Corp. Borg-Warner Chems. Plastics Div.	Ottawa, IL	19 (200)
	Washington, WV	120 (265)
Dart Indust. Inc. Chem. Group Plastic Raw Materials Sector Rexene Polymers Co.	Joliet, IL	25 (55)
Dow Chem. U.S.A.	Gales Ferry, CT	30 (65)
	Midland, MI	32 (70)
	Pevely, MO	450 (100)
	Torrence, CA	9 (20)
Foster Grant Co., Inc.	Leominster, MA	n.a.
The Goodrich Co. B. F. Goodrich Chem. Co., div.	Louisville, KY	14 (30)
Carl Gordon Indust., Inc.	Worcester, MA	n.a.
Hammond Plastics Div.	Oxford, MA	n.a.
Monsanto Co. Monsanto Polymers & Petrochems. Co.	Addyston, OH	145 (320)
	Muscatine, IA	57 (125)
Union Carbide Corp. Chems. and Plastics Div.	Bound Brook, NJ	14 (30)
Uniroyal, Inc. Uniroyal Chem., div.	Baton Rouge, LA	91 (200)
	Scotts Bluff, LA	
		TOTAL 672 (1480)

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[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs. annually

Source: Directory of Chemical Producers, 1976.

Table C-6. ALKYD RESIN PRODUCERS[2]

(Includes alkyd molding compounds)

Company	Location	Capacity[1] Gg(10^6 lbs)
ADCO Chem. Co., Inc.	Newark, NJ	
Allied Chem. Corp.		
Specialty Chems. Div.	Los Angeles, CA Toledo, OH	
American Cyanamid Co.		
Indust. Chems. and Plastics Div.	Azusa, CA	
Ashland Oil, Inc.		
Lehigh Valley Chem. Co., div.		
Resins and Plastics Div.	Los Angeles, CA Newark, NJ Pensacola, FL Valley Park, MO	
AZS Corp.		
A Z Products, Inc., div.	Eaton Park, FL	
AZS Chem. Co. Div.	Atlanta GA	
Ball Chem. Co.		
Resin Div.	Glenshaw, PA	
Barrett Varnish Co.	Cicero, IL	
Beatrice Foods Co.		
Beatrice Chem. Div.		
Farboil Co., div.	Baltimore, MD	
Bennett's	Salt Lake City, UT	
Bisonite Co., Inc.		
McDougall-Butler Div.	Buffalo, NY	
M. A. Bruder & Sons, Inc.	Philadelphia, PA	
Cargill, Inc.		
Chem. Products Div.	Carpentersville, IL Lynwood, CA Philadelphia, PA	

Table C-6 (Continued). ALKYD RESIN PRODUCERS[2]
(Includes alkyd molding compounds)

Company	Location	Capacity[1] Gg(10⁶ lbs)
Celanese Corp.		
Celanese Coatings and Specialty Chems. Co., subsid.		
Celanese Resins Div.	Belvidere, NJ	
	Los Angeles, CA	
	Louisville, KY	
Chem. Processors, Inc.	Seattle, WA	
Chem. Products Corp.	Elmwood Park, NJ	
Conchemco Inc.		
Baltimore Operations	Baltimore, MD	
Kansas City Operations	Kansas City, MO	
Cook Paint & Varnish Co.	Detroit, MI	
	Houston, TX	
	Milpitas, CA	
	North Kansas City, MO	
Degen Oil & Chem. Co.	Jersey City, NJ	
De Soto, Inc.	Berkeley, CA	
	Chicago Heights, IL	
	Garland, TX	
The Dexter Corp.		
Midland Div.	Cleveland, OH	
	Hayward, CA	
	Rocky Hill, CT	
	Waukegan, IL	
Dock Resins Corp.	Linden, NJ	
E. I. du Pont de Nemours & Co., Inc.		
Fabrics and Finishes Dept.	Chicago, IL	
	Flint, MI	
	Fort Madison, IA	
	Parlin, NJ	
	Philadelphia, PA	
	South San Francisco, CA	
	Toledo, OH	
	Tucker, GA	

Table C-6 (Continued). ALKYD RESIN PRODUCERS[2]
(Includes alkyd molding compounds)

Company	Location	Capacity[1] Gg(10^6 lbs)
Elliott Paint & Varnish Co. Armstrong Paint Co., div.	Chicago, IL	
ELT Inc. Baltimore Paint & Chem. Corp., subsid.	Baltimore, MD	
Emkay Chem. Co.	Elizabeth, NJ	
Essex Chem. Corp. BFC Div.	Sayreville, NJ	
Exxon Corp. Exxon Chem. Co., div. Exxon Chem. Co. U.S.A.	Houston, TX	
Foy-Johnston, Inc.	Cincinnati, OH	
The P. D. George Co.	St. Louis, MO	
Gilman Paint & Varnish Co.	Chattanooga, TN	
W. R. Grace & Co. Hatco Group Hatco Polyesters Div.	Colton, CA	
Grow Chem. Corp. Boysen Paint Co., subsid.	Oakland, CA	
Guardsman Chems., Inc.	Grand Rapids, MI	
Handschy Chem. Co. Farac Oil & Chem. Co., div.	Riverdale, IL	
Hanna Chem. Coatings Corp. Hanna Chem. Coatings Co., subsid.	Columbus, OH Birmingham, AL	
Hugh J.-Resins Co.	Long Beach, CA	
Inmont Corp.	Anaheim, CA Cincinnati, OH Detroit, MI Greenville, OH Los Angeles, CA	

Table C-6 (Continued). ALKYD RESIN PRODUCERS[2]
(Includes alkyd moding compounds)

Company	Location	Capacity[1] Gg(10^6 lbs)
Insilco Corp.		
The Enterprise Companies, div.	Wheeling, IL	
Frisch & Co., div.	Paterson, NJ	
Internat'l Minerals & Chem. Corp. Chem. Group Commercial Solvents Corp., subsid. McWhorter Chems. Co. Div.	Carpentersville, IL	
Interplastic Corp. Commercial Resins Div.	Minneapolis, MN	
Iovite Chems., Inc.	Matteson, IL	
Jones-Blair Co.	Dallas, TX	
Kelly-Moore Paint Co.	San Carlos, CA	
Kohler-McLister Paint Co.	Denver, CO	
Koppers Co., Inc. Organic Materials Div.	Bridgeville, PA	
Kyanize Paints, Inc.	Everett, MA	
Lawter Chems., Inc. Stresen-Reuter Div.	Bensenville, IL	
Lilly Indust. Coatings, Inc.	Indianapolis, IN Montebello, CA	
Marcor Inc. Montgomery Ward & Co., subsid. Standard T. Chem. Co., Inc., subsid.	Chicago Heights, IL Staten Island, NY	
McCloskey Varnish Co.	Los Angeles, CA Philadelphia, PA Portland, OR	

Table C-6 (Continued). ALKYD RESIN PRODUCERS[2]
(Includes alkyd molding compounds)

Company	Location	Capacity[1] Gg(10^6 lbs)
Midwest Mfg. Corp.	Burlington, IA	
Mobil Oil Corp. Mobil Chem. Co., div. Chem. Coatings Div.	Cleveland, OH Edison, NJ Kankakee, IL Rochester, PA	
Benjamin Moore & Co.	Cleveland, OH Los Angeles, CA Melrose Park, IL Newark, NJ	
Morris Indust. Inc. Lanson Chem. Co., div.	East St. Louis, IL	
Napko Corp.	Houston, TX	
N L Indust., Inc. Indust. Chems. Div.	Philadelphia, PA	
A. P. Nonweiler Co.	Oshkosh, WI	
Norris Paint & Varnish Co.	Salem, OR	
The O'Brien Corp.	Baltimore, MD South Bend, IN	
Fuller-O'Brien Corp., subsid.	South San Francisco, CA	
Onyx Oils & Resins, Inc.	Brooker, FL Newark, NJ	
C. J. Osborn Chems., Inc.	Pennsauken, NJ	
Perry & Derrick Co.	Dayton, KY	
Pervo Paint Co.	Los Angeles, CA	
Plastics Engineering Co.	Sheboygan, WI	
Polychrome Corp. Cellomer Corp., subsid.	Newark, NJ	

Table C-6 (Continued). ALKYD RESIN PRODUCERS[2]
(Includes alkyd molding compounds)

Company	Location	Capacity[1] Gg(10^6 lbs)
PPG Indust., Inc.		
Coatings and Resins Div.	Circleville, OH	
	East Point, GA	
	Houston, TX	
	Oak Creek, WI	
	Springdale, PA	
	Torrance, CA	
Pratt & Lambert, Inc.	Buffalo, NY	
Red Spot Paint & Varnish Co., Inc.	Evansville, IN	
Reichhold Chems., Inc.	Azusa, CA	
	Detroit, MI	
	Elizabeth, NJ	
	Houston, TX	
	Jacksonville, FL	
	South San Francisco, CA	
	Tuscaloosa, AL	
Sterling Div.	Sewickley, PA	
Reliance Universal Inc.		
Chem. Coatings and Resins Group	Brea, CA	
	Clinton, MS	
	High Point, NC	
	Houston, TX	
	Louisville, KY	
	Roanoke, VA	
	Salem, OR	
	Somerset, NJ	
	Sunnyvale, CA	
	Virginia Beach, VA	
	Zion, IL	
Resinous Chems. Corp.	Linden, NJ	
Resyn Corp.	Linden, NJ	
H. H. Robertson Co.		
Freeman Chem. Corp., subsid.	Chatham, VA	
	Saukville, WI	
Rohm and Haas Co.	Philadelphia, PA	

Table C-6 (Continued). ALKYD RESIN PRODUCERS[2]
(Includes alkyd molding compounds)

Company	Location	Capacity[1] Gg(10^6 lbs)
Sapolin Paints, Inc.	Brooklyn, NY	
Schenectady Chems., Inc.	Schenectady, NY	
SCM Corp.		
Glidden-Durkee Div.		
Coatings and Resins Group	Chicago, IL Cleveland, OH Reading, PA San Francisco, CA	
The Sherwin-Williams Co.	Chicago, IL Cleveland, OH Dayton, OH Detroit, MI Emeryville, CA Garland, TX Gibbsboro, NJ Newark, NJ	
Sullivan Chem. Coatings	Chicago, IL	
Sybron Corp.		
Jersey State Chem. Co., div.	Haledon, NJ	
Syncon Resins Inc.		
Farnow, Inc., div.	South Kearny, NJ	
T. F. Washburn Co., div.	Chicago, IL	
Synres Chem. Corp.	Anaheim, CA Elkhart, IN Kenilworth, NJ	
Shanco Plastics & Chems., subsid.	Tonawanda, NY	
Textron Inc.		
Indust. Product Group		
Spencer Kellogg Div.	Baltimore, MD	
Kelly-Pickering Chems. Dept.	San Carlos, CA	
Union Camp Corp.		
Chem. Products Div.	Valdosta, GA	
Valspar Corp.		
Midwest Synthetics Co., div.	Rockford, IL	

Table C-6 (Continued). ALKYD RESIN PRODUCERS[2]
(Includes alkyd molding compounds)

Company	Location	Capacity[1] Gg(10⁶ lbs)
Westinghouse Electric Corp. Insulating Materials Div.	West Miffin, PA	
Whittaker Corp. Whittaker Coatings and Chems. Mol-Rez Div.	Minneapolis, MN	
Yenkin-Majestic Paint Corp. Ohio Polychemicals Co., div.	Columbus, OH	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-7. ALKYL PHENOL-ACETYLENE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10⁶ lbs)
Polymer Applications, Inc.	Tonawanda, NY	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-8. ANILINE-FORMALDEHYDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Union Carbide Corp. Chems. and Plastics Div.	Bound Brook, NJ	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercailly salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-9. BUTYL PHENOL-FORMALDEHYDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Magna Corp.	Houston, TX	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-10. CELLULOSE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Dow Chem. U.S.A.	Midland, MI	
Eastman Kodak Co. Eastman Chem. Products, Inc., subsid. Tennessee Eastman Co., div.	Kingsport, TN	
Marcor Inc. Montgomery Ward and Co., subsid. Standard T Chem. Co., Inc., subsid.	Linden, NJ	
Tenneco Inc. Tenneco Chems., Inc. Foam and Plastics Div.	Nixon, NJ	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-11. COUMARONE-INDENE AND HYDROCARBON RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Chemfax, Inc.	Gulfport, MS	
De Soto, Inc.	Chicago Heights, IL	
Exxon Corp. Exxon Chemicals Co., div. Exxon Chem. Co. U.S.A.	Baton Rouge, LA[3]	
The Goodyear Tire & Rubber Co. Chem. Div.	Beaumont, TX	
Hercules Inc. Organics Dept.	Baton Rouge, LA Clairton, PA West Elizabeth, PA	
Neville Chem. Co.	Anaheim, CA Neville Island, PA	
Northwest Indust., Inc. Velsicol Chem. Corp., subsid.	Marshall, IL	
Reichhold Chems., Inc. Newport Div.	Gulfport, MS	
Schenectady Chems., Inc.	Rotterdam Junction, NY	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

[3] An expansion which will increase "Escorez" hydrocarbon resins capacity to 200 million pounds per year is scheduled for completion in 1977.

Source: Directory of Chemical Producers, 1976.

Table C-12. CRESOL-FORMALDEHYDE RESINS PRODUCERS[2] (Unmodified)

Company	Location	Capacity[1] Gg(10^6 lbs)
The Bendix Corp. Friction Materials Div.	Troy, NY	
Borden Inc. Borden Chem. Div. Adhesives and Chems. Div.-East	Bainbridge, NY Fayetteville, NC	
The Budd Co. Plastic Products Div.	Brigeport, PA	
Georgia-Pacific Corp. Chem. Div.	Conway, NC Lufkin, TX	
Reichhold Chems., Inc. Varcum Chem. Div.	Detroit, MI Niagara Falls, NY	
Schenectady Chems., Inc.	Rotterdam Junction, NY Schenectady, NY	
Union Carbide Corp. Chems. and Plastics Div.	Bound Brook, NJ	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-13. CRESYLIC ACID-FORMALDEHYDE RESIN PRODUCERS[2]
(Unmodified)

Company	Location	Capacity[1] Gg(10^6 lbs)
The Budd Co. Plastic Products Div.	Bridgeport, PA	
Monogram Indust., Inc. Spaulding Fibre Co., subsid.	De Kalb, IL Tonawanda, NY	
Napko Corp.	Houston, TX	
Reichhold Chems., Inc. Varcum Chem. Div.	Detroit, MI Niagara Falls, NY	
Schenectady Chems., Inc.	Rotterdam Junction, NY Schenectady, NY	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-14. DIALLYL PHTHALATE RESIN PRODUCTS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Allied Chem. Corp. Specialty Chems. Div.	Los Angeles, CA Toledo, OH	
FMC Corp. Chem. Group Indust. Chem. Div.	Baltimore, MD	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-15. DICYANDIAMIDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
American Cyanamid Co. Indust. Chems. and Plastics Div.	Wallingford, CT	
Apex Chem. Co., Inc.	Elizabethport, NJ	
De Paul Chem. Co., Inc.	Long Island City, NY	
ICI United States Inc. Mgf. Div. for Specialty Chems. and Dyes & Textile Chems.	Dighton, MA	
Kewanee Indust. Inc. Millmaster Onyx Corp., subsid. Refined-Onyx Div.	Lyndhurst, NJ	
United Merchants & Mfgs., Inc. Valchem-Chem. Div.	Langley, SC	
USM Corp. Crown-Metro, Inc., subsid.	Greenville, SC	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs. annually

Source: Directory of Chemical Producers, 1976.

Table C-16. DIMETHYL HYDANTOIN-FORMALDEHYDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Glyco Chems., Inc.	Williamsport, PA	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-17. EPOXY RESIN PRODUCERS[2]
(Unmodified)

Company	Location	Capacity[1] Gg(10^6 lbs)
Celanese Corp. Celanese Coatings and Specialty Chems. Co., subsid. Celanese Resins Div.	Louisville, KY	11 (25)
Ciba-Geigy Corp. Plastics and Additives Div. Resins Dept.	Toms River, NJ	27 (60)
Dow Chem. U.S.A.	Freeport, TX	34 (75)
Polychrome Corp. Cellomer Corp., subsid.	Newark, NJ	n.a.
Pratt & Lambert, Inc.	Buffalo, NY	n.a.
Reichhold Chems., Inc.	Andover, MA Azusa, CA Detroit, MI Houston, TX	15 (32)
Resyn Corp.	Linden, NJ	11 (25)
Seton Co. Wilmington Chem. Corp., div.	Wilmington, DE	2 (4)
Shell Chem. Co. Polymers and Detergent Products	Deer Park, TX	45 (100)
Union Carbide Corp. Chems. and Plastics Div.	Taft, LA	3 (6)
		TOTAL 148 (327)

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-18. EPOXY RESIN PRODUCERS[2]
(Modified)

Company	Location	Capacity[1] Gg(10^6 lbs)
Adhesive Products Corp.	Bronx, NY	
Allied Chem. Corp. Specialty Chems. Div.	Los Angeles, CA Toledo, OH	
Allied Products Corp. Acme Chems. Div.	New Haven, CT	
American Can Co. M&T Chems. Inc., subsid. Furane Plastics, Inc., subsid.	Los Angeles, CA	
Applied Plastics Co. Inc.	El Segundo, CA	
Ashland Oil, Inc. Lehigh Valley Chem. Co., div. Resins and Plastics Div.	Valley Park, MO	
Bennett's	Salt Lake City, UT	
Carboline Co. Moran Paint Co., subsid.	Xenia, OH	
Celanese Corp. Celanese Coatings and Specialty Chems. Co., subsid. Celanese Resins Div.	Belvidere, NJ Los Angeles, CA Louisville, KY	
Ciba-Geigy Corp. Plastics and Additives Div. Resins Dept.	McIntosh, AL	
Cook Paint & Varnish Co.	Detroit, MI Houston, TX North Kansas City, MO	
Degan Oil & Chem. Co.	Jersey City, NJ	
Dennis Chem. Co.	St. Louis, MO	

Table C-18 (Continued). EPOXY RESIN PRODUCERS[2] (Modified)

Company	Location	Capacity[1] Gg(10^6 lbs)
De Soto, Inc.	Berkeley, CA Chicago Heights, IL Garland, TX	
The Dexter Corp.		
Hysol Div.	City of Industry, CA Olean, NY	
Midland Div.	Cleveland, OH Hayward, CA Rocky Hill, CT Waukegan, IL	
Dow Chem. U.S.A.	Torrance, CA	
Elliott Paint & Varnish Co.		
Armstrong Paint Co., div.	Chicago, IL	
Essex Chem. Corp.		
BFC Div.	Sayreville, NJ	
The Flamemaster Corp.		
Chem-Seal Corp., div.	Sun Valley, CA	
Guardsman Chems., Inc.	Grand Rapids, MI	
Hardman Inc.	Belleville, NJ	
Hexcel Corp.		
Rezolin Div.	Chatsworth, CA	
Inmont Corp.	Cincinnati, OH Greenville, OH	
Isochem Resins Co.	Lincoln, RI	
Lawter Chems., Inc.		
Stresen-Reuter Div.	Bensenville, IL	
Marcor Inc.		
Montgomery Ward & Co., subsid.		
Standard T Chem. Co., Inc., subsid.	Chicago Heights, IL Dallas, TX Staten Island, NY	
Midwest Mfg. Corp.	Burlington, IA	

Table C-18 (Continued). EPOXY RESIN PRODUCERS[2] (Modified)

Company	Location	Capacity[1] Gg(10^6 lbs)
Mobil Oil Corp. Mobil Chem. Co., div. Chem. Coatings Div.	Cleveland, OH Kankakee, IL Pittsburgh, PA	
Napco Corp.	Houston, TX	
North American Philips Corp. Thompson-Hayward Chem. Co., subsid. Leffingwell Chem. Co., subsid.	Brea, CA	
The O'Brien Corp. Fuller-O'Brien Corp., subsid.	South Bend, IN South San Francisco, CA	
Onyx Oils & Resins Inc.	Newark, NJ	
C. J. Osborn Chems., Inc.	Pennsauken, NJ	
Owens-Corning Fiberglas Corp. Resins and Coatings Div.	Anderson, SC	
Plastics Engineering Co.	Sheboygan, WI	
Poly Resins, Inc.	Sun Valley, CA	
PPG Indust., Inc. Coatings and Resins Div.	East Point, GA Houston, TX Oak Creek, WI Torrance, CA	
Reichhold Chems., Inc.	Azusa, CA Detroit, MI Elizabeth, NJ South San Francisco, CA	
Sterling Div.	Sewickley, PA	
Resyn Corp.	Linden, NJ	
Schenectady Chems., Inc.	Schenectady, NY	

Table C-18 (Continued). EPOXY RESIN PRODUCERS[2] (Modified)

Company	Location	Capacity[1] Gg(10^6 lbs)
SCM Corp. Glidden-Durkee Div. Coatings and Resins Group	Chicago, IL Cleveland, OH Reading, PA San Francisco, CA	
Seton Co. Wilmington Chem. Corp., div.	Wilmington, DE	
Shell Chem. Co. Base Chems	Deer Park, Texas[3]	
The Sherwin-Williams Co.	Chicago, IL	
Syncon Resins, Inc.		
Farnow, Inc., div.	South Kearny, NJ	
T. F. Washburn Co., div.	Chicago, IL	
Synres Chem. Corp.	Kenilworth, NJ	
Synthane-Taylor Corp.	Betzwood, PA LaVerne, CA	
United States Gypsum Co.	Gypsum, OH	
Permalastic Products Co., subsid.	Detroit, MI Trenton, NJ	
Valspar Corp.	Minneapolis, MN	
Westinghouse Electric Corp. Insulating Materials Div.	West Mifflin, PA	
Whittaker Corp. Whittaker Coatings and Chems. Wooster Universal Div.	Wooster, OH	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

[3] A new 200 million pound-per-year epoxy resins plant is planned; construction is expected to begin in late 1976 and be completed in late 1978

Source: Directory of Chemical Producers, 1976.

Table C-19. ETHYLENE-MALEIC ANHYDRIDE COPOLYMER RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Monsanto Co.		
Monsanto Indust. Chems. Co.	Luling, LA	
	Texas City, TX	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976

Table C-20. ETHYLENE-VINYL ACETATE COPOLYMER RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Air Products and Chems., Inc. Polymer Chems. Div.	Calvert City, KY Middlesex, NJ[3]	
Allied Chem. Corp. Specialty Chems. Div.	Orange, TX	
Borden Inc. Borden Chem. Div. Thermoplastic Products	Bainbridge, NY Compton, CA Demopolis, AL Illiopolis, IL Leominster, MA	
Dow Chem. U.S.A.	Midland, MI	
E. I. du Pont de Nemours & Co., Inc. Plastics Products and Resins Dept.	Orange, TX Seneca, IL	
Polymer Intermediates Dept.	Seneca, IL	
National Distillers and Chem. Corp. Chems. Div. U.S. Indust. Chems. Co., div.	Tuscola, IL	
Union Carbide Corp. Chems. and Plastics Div.	Institute and South Charleston, WV	
Union Oil Co. of California AMSCO Div.	Charlotte, NC La Mirada, CA	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs. annually

[3] An expansion of ethylene-vinyl acetate copolymer resins which doubled capacity has come on stream since January 1, 1976

Source: Directory of Chemical Producers, 1976.

Table C-21. FLUOROCARBON RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Allied Chem. Corp. Specialty Chems. Div.	Elizabeth, NJ	
E. I. du Pont de Nemours & Co., Inc. Plastics Products and Resins Dept.	Parkersburg, WV	
ICI United States Inc. Plastics Div.	Bayonne, NJ	
Marcor Inc. Montgomery Ward & Co., subsid. Standard T Chem. Co., Inc., subsid.	Staten Island, NY	
Minnesota Mining and Mfg., Co. Commercial Chems. Div.	Decatur, AL	
Pennwalt Corp. Chem. Div.	Calvert City, KY	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercailly salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-22. FURAN RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
American Can Co. M&T Chems. Inc., subsid. Furane Plastics, Inc., subsid.	Los Angeles, CA	
Ashland Oil, Inc. Ashland Chem. Co., div. Chem. Products Div.	Hammond, IN	
Combustion Engineering, Inc. C-E Cast Indust. Products Div.	Muse, PA	
Core-Lube, Inc.	Grovelane, IL	
CPC Internat'l Inc. Acme Resin Co., div.	Forest Park, IL	
Delta Oil Products Corp.	Milwaukee, WI	
Eronel Indust.	Hawthorne, CA	
ESB Inc. Atlas Minerals and Chems. Div.	Mertztown, PA	
Hercules Inc. Haveg Indust., Inc., subsid. Marshallton Operation	Wilmington, DE	
Hill & Griffith Co. Mar-Cam Div.	Hickory, NC	
Internat'l Minerals & Chem. Corp. Aristo Internat'l Corp., subsid. Foundry Products Div.	Detroit, MI	

Table C-22 (Continued). FURAN RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Koppers Co., Inc. Thiem Corp., subsid.	Milwaukee, WI Oak Creek, WI	
Kordell Indust.	Mishawaka, IN	
Occidental Petroleum Corp. Hooker Chems. and Plastics Corp., subsid. Durez Div.	Kenton, OH North Tonawanda, NY	
Reichhold Chems., Inc. Varcum Chem. Div.	Niagara Falls, NY	
United-Erie, Inc.	Erie, PA	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-23. GLYOXAL-FORMALDEHYDE RESINS PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
National Starch and Chem. Corp. Proctor Chem. Co., subsid.	Salisbury, NC	
U.S. Oil Co. Southern U.S. Chem. Co., Inc., subsid.	Rock Hill, SC	
USM Corp. Crown-Metro, Inc., subsid.	Greenville, SC	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-24. IONOMER RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
E. I. du Pont de Nemours & Co. Plastics Products and Resins Dept.	Orange, TX	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-25. KETONE-ALDEHYDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Sun Chem. Corp. Chems. Group Chems. Div.	Chester, SC	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-26. MALEIC RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Synres Chem. Corp.	Kenilworth, NJ	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-27. MELAMINE-FORMALDEHYDE RESINS PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Allied Chem. Corp.		
Specialty Chems. Div.	Toledo, OH	
American Cyanamid Co.		
Indust. Chems. and Plastics Div.	Azusa, CA	
	Kalamazoo, MI	
	Wallingford, CT	
Organic Chems. Div.	Charlotte, NC	
Formica Corp., subsid.	Evandale, OH	
Ashland Oil, Inc.		
Lehigh Valley Chem. Co., div.		
Resins and Plastics Div.	Calumet City, IL	
	Fords, NJ	
	Los Angeles, CA	
Borden Inc.		
Borden Chem. Div.		
Adhesives and Chems. Div. West	Kent, WA	
	Springfield, OR	
Cargill, Inc.		
Chem. Products Div.	Carpentersville, IL	
	Lynwood, CA	
	Philadelphia, PA	
Celanese Corp.		
Celanese Coatings and Specialty Chems. Co., subsud.		
Celanese Resins Div.	Louisville, KY	
Commercial Products Co.	Hawthorne, NJ	
Cook Paint & Varnish Co.	Detroit, MI	
	North Kansas City, MO	
Dan River, Inc.	Danville, VA	
Dock Resins Corp.	Linden, NJ	

Table C-27 (Continued). MELAMINE-FORMALDEHYDE RESINS PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Georgia-Pacific Corp. Chem. Div.	Albany, OR	
	Columbus, OH	
	Conway, NC	
	Coos Bay, OR	
	Louisville, MS	
	Lufkin, TX	
	Russellville, SC	
	Savannah, GA	
	Taylorsville, MS	
	Vienna, GA	
Guardsman Chems., Inc.	Grand Rapids, MI	
Gulf Oil Corp. Gulf Oil Chems. Co., div. Indust. and Specialty Chems. Div.	High Point, NC	
	Lansdale, PA	
	Shawano, WI	
	West Memphis, AR	
Hart Products Corp.	Jersey City, NJ	
Koppers Co., Inc. Organic Materials Div.	Bridgeville, PA	
Mobil Oil Corp. Mobil Chem. Co. div. Chem. Coatings Div.	Kankakee, IL	
Monsanto Co. Monsanto Polymers & Petrochems. Co.	Addyston, OH	
	Chocolate Bayou, TX	
	Eugene, OR	
	Santa Clara, CA	
	Springfield, MA	

Table C-27 (Continued). MELAMINE-FORMALDEHYDE RESINS PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
National Starch and Chem. Corp. Proctor Chem. Co., subsid.	Salisbury, NC	
Onyx Oils & Resins, Inc.	Brooker, FL Newark, NJ	
Owens-Corning Fiberglas Corp. Resins and Coatings Div.	Newark, OH	
Perstorp U.S. Inc.	Florence, MA	
Plastics Engineering Co.	Sheboygan, WI	
Plastics Mfg. Co.	Dallas, TX	
PPG Indust., Inc. Coatings and Resins Div.	Circleville, OH Oak Creek, WI	
Reichhold Chems., Inc.	Andover, MA Detroit, MI Malvern, AR South San Francisco,CA Tacoma, WA Tuscaloosa, AL White City, OR	
Reliance Universal Inc. Chem. Coatings and Resins Group	Brea, CA Clinton, MI High Point, NC Houston, TX Louisville, KY Roanoke, VA Salem, OR Somerset, NJ Sunnyvale, CA Virginia Beach, VA Zion, IL	
Renroh Inc.	New Bern, NC	
Riegel Textile Corp. H.I.T. Chems. Div.	Ware Shoals, SC	

Table C-27 (Continued). MELAMINE-FORMALDEHYDE RESINS PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Rohm and Haas Co.	Philadelphia, PA	
Scher Brothers, Inc.	Clifton, NJ	
Scott Paper Co. Packaged Products Div.	Chester, PA Mobile, AL	
The Sherwin-Williams Co.	Cleveland, OH Newark, NJ	
Skelly Oil Co. Chembond Corp., subsid.	Springfield, OR	
Sou-Tex Chem. Co., Inc.	Mount Holly, NC	
Sun Chem. Corp. Chems. Group Chems. Div.	Chester, SC	
Sybron Corp. Jersey State Chem. Co., div.	Haledon, NJ	
Synthane-Taylor Corp.	Betzwood, PA LaVerne, CA	
Synthron, Inc.	Ashton, RI Morganton, NC	
United Merchants & Mfgs., Inc. Valchem - Chem. Div.	Langley, SC	
U.S. Oil Co.	East Providence, RI	
Southern U.S. Chem. Co., Inc. subsid.	Rock Hill, SC	
Univar Corp. Pacific Resins & Chems., Ind., subsid.	Newark, OH Portland, OR Richmond, CA	

Table C-27 (Continued). MELAMINE-FORMALDEHYDE RESINS PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Virginia Chems. Inc. Indust. Chems. Dept.	Portsmouth, VA	
Westinghouse Electric Corp. Insulating Materials Div.	West Mifflin, PA	
Weyerhaeuser Co.	Longview, WA Marshfield, WI	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually.

[3] A methylated melamine-formaldehyde resins plant is planned, completion is scheduled for 1976.

Source: Directory of Chemical Producers, 1976.

Table C-28. METHYL VINYL ETHER-MALEIC ANHYDRIDE COPOLYMER RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
GAF Corp. Chem. Products	Calvert City, KY	

[1]On stream as of January 1, 1976

[2]Producers considered manufacture materials in commercailly salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-29. METHYL VINYL ETHER-MONO BUTYL MALEATE COPOLYMER RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
GAF Corp. Chem. Products	Calvert City, KY	

[1]On stream as of January 1, 1976

[2]Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs. annually

Source: Directory of Chemical Producers, 1976.

Table C-30. METHYL VINYL ETHER-MONO ETHYL MALEATE COPOLYMER RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
GAF Corp. Chem. Products	Calvert City, KY	

[1]On stream as of January 1, 1976

[2]Producers considered manufacture materials in commercailly salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-31. METHYL VINYL ETHER POLYMER RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
GAF Corp. Chem. Products	Calvert City, KY	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-32. PHENOL-FORMALDEHYDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10⁶ lbs)
Allied Chem. Corp. Specialty Chems. Div.	Los Angeles, CA	
	Toledo, OH	
American Cyanamid Co. Formica Corp., subsid.	Evandale, OH	
Ashland Oil, Inc. Lehigh Valley Chem. Co., div. Resins and Plastics Div.	Calumet City, IL	
	Fords, NJ	
	Newark, NJ	
	Pensacola, FL	
The Bendix Corp. Friction Materials Div.	Troy, NY	
Borden Inc. Borden Chem. Div. Adhesives and Chems. Div. - East	Bainbridge, NY	
	Demopolis, AL	
	Diboll, TX	
	Fayetteville, NC	
	Sheboygan, WI	
Adhesives and Chems. Div. - West	Fremont, CA	
	Kent, WA	
	La Grande, OR	
	Missoula, MT	
	Springfield, OR	
The Budd Co. Plastic Products Div.	Bridgeport, PA	
Carboline Co. Moran Paint Co., subsid.	Xenia, OH	
The Carborundum Co. Polymers Venture	Niagara Falls, NY	
Champion Internat'l Corp. U.S. Plywood Div.	Anderson, CA	
Clark Oil & Refining Corp. Clark Chem. Corp., subsid.	Blue Island, IL	

Table C-32 (Continued). PHENOL-FORMALDEHYDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
CPC Internat'l Inc. Acme Resin Co., div.	Forest Park, IL	
De Soto, Inc.	Berkeley, CA	
	Chicago Heights, IL	
	Garland, TX	
Gen. Electric Co. Plastics Business Div. Engineering Plastics Product Dept.	Pittsfield, MA	
The P.D. George Co.	St. Louis, MO	
Georgia-Pacific Corp. Chem. Div.	Albany, OR	
	Columbus, OH	
	Conway, NC	
	Coos Bay, OR	
	Crossett, AR	
	Louisville, MS	
	Lufkin, TX	
	Russellville, SC	
	Savannah, GA	
	Taylorsville, MS	
	Vienna, GA	
Gulf Oil Corp. Gulf Oil Chems. Co., div. Indust. and Specialty Chems. Div.	High Point, NC	
	Lansdale, PA	
Hercules Inc. Haveg Indust., Inc., subsid. Marshallton Operation	Wilmington, DE	
Heresite & Chem. Co.	Manitowoc, WI	
IC Indust., Inc. Abex Corp., subsid. Friction Products Group	Troy, MI	

Table C-32 (Continued). PHENOL-FORMALDEHYDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg (10^6 lbs)
Inland Steel Co. Inland Steel Container Co., div.	Alsip, IL	
Inmont Corp.	Anaheim, CA Chicago, IL Cincinnati, OH Elizabeth, NJ Grand Rapids, MI Greenville, OH Huntington, IN Los Angeles, CA Morganton, NC	
The Ironsides Co.	Columbus, OH	
Kewanee Indust., Inc. Millmaster Onyx Corp., subsid. Refined-Onyx Div.	Lyndhurst, NJ	
Knoedler, Alphonse & Co. Knoedler Chem. Co., subsid.	Lancaster, PA	
Koppers Co., Inc. Organic Materials Div.	Petrolia, PA	
Lawter Chems., Inc.	South Kearny, NJ	
Masonite Corp. Alpine Div.	Gulfport, MS	
Monogram Indust., Inc. Spaulding Fibre Co., subsid.	De Kalb, IL Tonawanda, NY	
Monsanto Co. Monsanto Polymers & Petrochems. Co.	Addyston, OH Chocolate Bayou, TX Eugene, OR Springfield, MA	
Napko Corp.	Houston, TX	

Table C-32 (Continued). PHENOL-FORMALDEHYDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Occidental Petroleum Corp. Hooker Chems. and Plastics Corp., subsid. Durez Div.	Kenton, OH North Tonawanda, NY	
Onyx Oils & Resins, Inc.	Brooker, FL Newark, NJ	
Owens-Corning Fiberglas Corp. Resins and Coatings Div.	Barrington, NJ Newark, OH Waxahachie, TX	
Pioneer Plastics Corp. Chem. Div.	Auburn, ME	
Plastics Engineering Co.	Sheboygan, WI	
Polymer Applications, Inc.	Tonawanda, NY	
Polyrez Co., Inc.	Woodbury, NJ	
Raybestos-Manhattan, Inc. Adhesives Dept.	Stratford, CT	
Reichhold Chems., Inc.	Andover, MA Azusa, CA Carteret, NJ Detroit, MI Elizabeth, NJ Houston, TX Kansas City, KS Moncure, NC South San Francisco, CA Tacoma, WA Tuscaloosa, AL White City, OR	
Varcum Chem. Div.	Niagara Falls, NY	
Rogers Corp.	Manchester, CT	
Rohm and Haas Co.	Philadelphia, PA	

Table C-32 (Continued). PHENOL- FORMALDEHYDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Schenectady Chems., Inc.	Rotterdam Junction, NY Schenectady, NY	
Simpson Timber Co. Chems. Div.	Portland, OR	
Skelly Oil Co. Chembond Corp., subsid.	Andalusia, AL Spokane, WA Springfield, OR Winnfield, LA	
Synres Chem. Corp.	Kenilworth, NJ	
Shanco Plastics & Chems., subsid.	Tonawanda, NY	
Union Carbide Corp. Chems. and Plastics Div.	Bound Brook, NJ Elk Grove, CA Marietta, OH Texas City, TX	
United-Erie, Inc.	Erie, PA	
Univar Corp. Pacific Resins & Chems., Inc., subsid.	Eugene, OR Newark, OH Portland, OR Richmond, CA	
Valentine Sugars, Inc. Valite Div.	Lockport, LA	
West Coast Adhesives Co.	Portland, OR	
Westinghouse Electric Corp. Insulating Materials Div.	West Miffin, PA	
Weyerhaeuser Co.	Longview, WA Marshfield, WI	

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[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-33. PHENOL-RESORCINOL-FORMALDEHYDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Gulf Oil Corp. Gulf Oil Chems. Co., div. Indust. and Specialty Chems. Div.	High Point, NC Lansdale, PA	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-34. POLYAMIDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)		
Allied Chem. Corp. Fibers Div.	Chesterfield, VA	8	(18)	Nylon 6
Alrac Corp.	Stamford, CT	1	(2)	Nylon 4, captive
AZS Corp. A Z Products, Inc., div.	Eaton Park, FL	2	(5)	Non-nylon resins[3]
Belding Heminway Co. Inc. Belding Chem. Indust., subsid.	Grosvenordale, CT	2	(4)	Nylon 66 and 69
Borden Inc. Borden Chem. Div. Adhesives and Chems. Div. - East	Bainbridge, NY	1	(2)	Paper-treating resins made by condensing a dibasic acid with a polyalkalene-polyamine and subsequently reacting this product with epichlorohydrin.
The Budd Co. Plastic Products Div.	Phoenixville, PA	n.a.		Nylon 6; Captive
Celanese Corp. Celanese Coatings and Specialty Chems. Co., subsid. Celanese Resins Div.	Louisville, KY	2	(5)	Non-nylon resins[3]
Cooper Polymers, Inc.	Wilmington, MA	1	(2)	Non-nylon resins[3]
Crosby Chems., Inc.	Picayune, MS	1	(1)	Non-nylon resins[1]
Custom Resins Inc.	Henderson, KY	4	(9)	Nylon 6
Dow Badische Co.	Freeport, TX	7	(15)	Nylon 6
E.I. Du Pont de Nemours & Co., Inc. Plastics Products and Resins Dept.	Parkersburg, WV	45 2	(100) (5)	Nylon 6, 66, 612 Non-nylon resins[3] for textiles and adhesives

Table C-34 (Continued). POLYAMIDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)		
El Paso Natural Gas Co. Beaunit Corp., subsid. Beaunit Fibers Div.	Etowah, TN	1	(2)	Nylon 66
Emery Indust., Inc.	Cincinnati, OH	5	(10)	Non-nylon resins[3]
The Firestone Tire & Rubber Co. Firestone Synthetic Fibers Co., div.	Hopewell, VA	4	(8)	Nylon 6
Foster Grant Co., Inc.	Manchester, NH	7	(15)	Nylon 6
Gen. Mills, Inc. Gen. Mills Chems., Inc., subsid. Indust. Chems. Operations	Kankakee, IL	11	(25)	
Hercules Inc. Organics Dept.	Chicopee, MA Hattiesburg, MS Milwaukee, WI Portland, OR Savannah, GA	11	(24)	Paper-treating resins made by condensing a dibasic acid with a polyalkalene-polyamine and subsequently reacting this product with epichlorohydrin.
Lawter Chems., Inc.	South Kearny, NJ	1	(1)	Non-nylon resins[3] for printing inks
Mobil Oil Corp. Mobil Chem. Co., div. Chem. Coatings Div.	Edison, NJ	1	(3)	Non-nylon resins[3]
Monsanto Co. Monsanto Polymers & Petrochems. Co.	Pensacola, FL	14	(30)	Nylon 66,69,610
	Springfield, MA	n.a.		
Napko Corp.	Houston, TX	<1	(<1)	Captive
Nylene Corp.	Jenkinsville, SC	2	(5)	Nylon 6
Reichhold Chems., Inc.	Andover, MA	1	(3)	Non-nylon resins[3]

Table C-34 (Continued). POLYAMIDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)		
Rilsan Corp. Rilsan Indust. Inc., div.	Birdsboro, PA	5	(12)	Nylon 11, 12
Shakespeare Co. Monofilament Div.	Columbia, SC	<1	(<1)	Nylon 6
Sun Chem. Corp. Chems. Group Chems. Div.	Chester, SC	1	(2)	Non-nylon resins[3] for printing inks
Union Camp Corp. Chem. Products Div.	Savannah, GA	3	(6)	Non-nylon resins[3]
Univar Corp. Pacific Resins & Chems. Inc., subsid.	Newark, OH Portland, OR Richmond, CA	1	(1)	Paper-treating resins made by condensing a dibasic acid with a polyalkalene-polyamine and subsequently reacting this product with epichlorohydrin.
USM Corp. Bostik Chem. Group Bostik Div.	Middleton, MA	1	(2)	Non-nylon resins[3]
	TOTAL	<145	(<319)	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

[3] Usually made by condensing vegetable oil acids with polyamines.

Source: Directory of Chemical Producers, 1976.

Table C-35. POLYBUTENE-1 RESINS PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Witco Chem. Corp. Polymer Div.	Taft, LA	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-36. POLYBUTYLENE TEREPHTHALATE PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Eastman Kodak Co. Eastman Chem. Products, Inc., subsid. Tennessee Eastman Co., div.	Kingsport, TN	
GAF Corp Chemical Products	Calvert City, KY[3]	
Gen. Electric Co. Plastics Business Div. Engineering Plastics Product Dept. (Valox®)	Mount Vernon, IN	
The Goodyear Tire & Rubber Co. Chem. Div.	Point Pleasant, WV	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually

[3] A new polybutylene terephthalate plant is planned; completion is scheduled for mid-1977

Source: Directory of Chemical Producers, 1976.

Table C-37. POLYCARBONATE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Gen. Electric Co. Plastics Business Div. Engineering Plastics Product Dept.	Mount Vernon, IN	68 (150)
Mobay Chem. Corp. Plastics & Coatings Div.	Cedar Bayou, TX	n.a.
	New Martinsville, WV	18 (40)
		TOTAL 86 (190)

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976

Table C-38. SATURATED POLYESTER RESINS PRODUCERS[2]
(Excludes resins for polyester fibers)

Company	Location	Capacity[1] Gg(10^6 lbs)
Adhesive Products Corp.	Bronx, NY[3]	
Allied Chem. Corp. Specialty Chems. Div. Nypel, Inc., subsid.	West Conshonocken, PA	
Borden Inc. Borden Chem. Div. Adhesives and Chems. Div. - East	Bainbridge, NY[4]	
The Carborundum Co. Polymers Venture	Niagara Falls, NY[3]	
Cargill, Inc. Chem. Products Div.	Carpentersville, IL	
	Lynwood, CA	
	Philadelphia, PA	
Cooper Polymers, Inc.	Wilmington, MA	
Degen Oil & Chem. Co.	Jersey City, NJ	
Gen. Electric Co. Plastics Business Div. Engineering Plastics Product Dept.	Mount Vernon, IN	
Gen. Mills, Inc. Gen. Mills Chems., Inc., subsid. Indust. Chems. Operations	Minneapolis, MN	
The P.D. George Co.	St. Louis, MO	
The Goodyear Tire & Rubber Co. Chem. Div.	Point Pleasant, WV[4],[5]	
Hanna Chem. Coatings Corp. Hanna Chem. Coatings Co., subsid	Birmingham, AL	
Henkel Inc. Textilana, Div.	Hawthorne, CA[3]	

Table C-38 (Continued). SATURATED POLYESTER RESINS PRODUCERS[2]
(Excludes resins for polyester fibers)

Company	Location	Capacity[1] Gg(10^6 lbs)
Henkel Inc. Textilana, Div.	Hawthorne, CA	
The O'Brien Corp. Fuller-O'Brien Corp., subsid	South San Francisco, CA	
Polymer Applications, Inc.	Tonawanda, NY	
Reichhold Chems., Inc. Sterling Div.	Sewickley, PA	
Resyn Corp	Linden, NJ	
The Sherwin-Williams Co.	Chicago, IL Newark, NJ	
USM Corp. Bostik Chem. Group Bostik Div.	Middleton, MA	
Valspar Corp. Midwest Synthetics Co., div.	Rockford, IL	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually

[3] For other uses (excluding oil-free alkyds)

[4] For films

[5] A 25% expansion of polyester resins capacity is planned, completion is scheduled for 1976.

Source: Directory of Chemical Producers, 1976.

Table C-39. UNSATURATED POLYESTER RESIN PRODUCERS[2]
(Includes alkyd molding compounds)

Company	Location	Capacity[1] Gg(10^6 lbs)
Alpha Chem. Corp.	Collierville, TN Kathleen, FL Perris, CA	
American Cyanamid Co. Indust. Chems. and Plastics Div.	Azusa, CA Perryburg, OH Wallingford, CT	
Ashland Oil, Inc. Lehigh Valley Chem. Co., div. Resins and Plastics Div.	Calumet City, IL Los Angeles, CA Newark, NJ Valley Park, MO	
AZS Corp. A Z Products, Inc. div.	Eaton Park, FL	
Barton Chem. Corp.	Chicago, IL	
Cargill, Inc. Chem. Products Div.	Carpentersville, IL Lynwood, CA Philadelphia, PA	
Cook Paint & Varnish Co.	Detroit, MI Hialeah, FL Houston, TX Milpitas, CA North Kansas City, MO	
De Soto, Inc.	Berkeley, CA Chicago Heights, IL Garland, TX	
Diamond Shamrock Corp. Diamond Shamrock Chem. Co. Plastics Div.	Oxnard, CA	
Eastman Kodak Co. Eastman Chem. Products, Inc., subsid. Texas Eastman Co., div.	Longview, TX	

Table C-39 (Continued). UNSATURATED POLYESTER RESIN PRODUCERS[2]
(Includes alkyd molding compounds)

Company	Location	Capacity[1] Gg(10^6 lbs)
The P. D. George Co.	St. Louis, MO	
W. R. Grace & Co. Hatco Group Hatco Polyesters Div.	Bartow, Fl Colton, CA Jacksonville, AR Linden, NJ Swanton, OH	
Guardsman Chems., Inc.	Grand Rapids, MI	
ICI United States Inc. Mfg. Div. for Specialty Chems. and Dyes & Textile Chems.	New Castle, DE	
Inmont Corp.	Cincinnati, OH Detroit, MI Greenville, OH	
Interplastic Corp. Commercial Resins Div.	Minneapolis, MN Pryor, OK	
Iovite Chems., Inc.	Matteson, IL	
Koppers Co., Inc. Organic Materials Div.	Bridgeville, PA Richmond, CA	
Mobay Chem. Corp. Plastics + Coatings Div.	New Martinsville, WV	
Mobil Oil Corp. Mobil Chem. Co., div. Chem. Coatings Div.	Pittsburgh, PA	
The O'Brien Corp. Fuller-O'Brien Corp.	South Bend, IN South San Francisco,CA	
Occidental Petroleum Corp. Hooker Chem. Corp., subsid. Hooker Chems. and Plastics Corp., subsid. Durez Div.	Kenton, OH North Tonawanda, NY	

Table C-39 (Continued). UNSATURATED POLYESTER RESIN PRODUCERS[2]
(Includes alkyd molding compounds)

Company	Location	Capacity[1] Gg(10⁶ lbs)
Onyx Oils & Resins, Inc.	Newark, NJ	
C. J. Osborn Chems., Inc.	Pennsauken, NJ	
Owens-Corning Fiberglas Corp.		
Resins and Coatings Div.	Anderson, SC	
	Valparaiso, Ind.	
Polychrome Corp.		
Cellomer Corp., subsid.	Newark, NJ	
PPG Indust., Inc.	Cheswold, DE[3]	
Coatings and Resins Div.	Circleville, OH	
	Houston, TX	
	Springdale, PA	
	Torrance, CA	
Reichhold Chems., Inc.	Azusa, CA[3]	
	Detroit, MI	
	Elizabeth, NJ	
	Houston, TX	
	Jacksonville, FL	
	Morris, IL[4]	
	South San Francisco, CA	
	Tacoma, WA	
Sterling Div.	Sewickley, PA	
Reliance Universal Inc.		
Chem. Coatings and Resins Group	Brea, CA	
	Clinton, MS	
	High Point, NC	
	Houston, TX	
	Louisville, KY	
	Roanoke, VA	
	Salem, OR	
	Somerset, NJ	
	Sunnyvale, CA	
	Virginia Beach, VA	
	Zion, IL	
Resinous Chems. Corp.	Linden, NJ	
Resyn Corp.	Linden, NJ	
H.H. Robertson Co.		
Freeman Chem. Corp., subsid.	Chatham, VA	
	Saukville, WI	

Table C-39 (Continued). UNSATURATED POLYESTER RESIN PRODUCERS[2]
(Includes alkyd molding compounds)

Company	Location	Capacity[1] Gg(10^6 lbs)
Rockwell Internat'l Corp. Automotive Products Div. Reinforced Plastics Operations	Ashtabula, OH	
Rohm and Haas Co.	Philadelphia, PA	
Rohm and Haas Tennessee Inc., subsid	Knoxville, NY	
Schenectady Chems., Inc.	Schenectady, NY	
SCM Corp. Glidden-Durkee Div. Coatings and Resins Group	Chicago, IL Cleveland, OH Huron, OH Reading, PA San Francisco, CA	
The Sherwin-Williams Co.	Cleveland, OH Emeryville, CA	
The Standard Oil Co. (Ohio) Vistron Corp., subsid. Chems. Dept. Filon/Silmar Div.	Covington, KY Hawthorne, CA	
Syncon Resins Inc.		
Farnow, Inc., div.	South Kearny, NJ	
T.F. Washburn Co., div.	Chicago, IL	
Synres Chem. Corp.	Anaheim, CA Elkhart, IN	
United-Erie, Inc.	Erie, PA	
United Merchants & Mfgs., Inc.		
American Plastics Div.	Elkhart, IN	
Glascoat Div.	Miami, FL	
Thalco Div.	Los Angeles, CA	
USM Corp. Bostik Chem. Group Bostik Div.	Middleton, MA	
Westinghouse Electric Corp. Insulating Materials Div.	West Mifflin, PA	

Table C-39 (Continued). UNSATURATED POLYESTER RESIN PRODUCERS[2]
(Includes alkyd molding compounds)

Company	Location	Capacity[1] Gg(10^6 lbs)
Whittaker Corp.		
Whittaker Coatings and Chems.		
Lenoir Div.	Lenoir, NC	
Mol-Rez Div.	Minneapolis, MN	
Ram Div.	Gardena, CA	

[1] On stream as of January 1, 1976.

[2] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually.

[3] A new polyester resins plant is planned

[4] An expansion is planned which will increase unsaturated polyester resins capacity to 130 million pounds per year; completion of the multi-million-dollar plant is scheduled for 1976.

[5] A new 100 million pound per year unsaturated polyester resins plant is under construction; completion is scheduled for mid-1976.

Source: Directory of Chemical Producers, 1976.

Table C-40. POLYETHYLENE RESIN PRODUCERS[16]

Company	Location	Capacity[15] Gg(10^6 lbs)		
Allied Chem. Corp. Specialty Chems. Div.	Baton Rouge, LA	100	(353)	H; Phillips
	Orange, TX	11	(25)	H
		18	(40)	L; Allied; PE emulsions
American Petrofina, Inc. Cosden Oil & Chem. Co., subsid.	Calumet City, IL	6	(13)	L; PE emulsions
ARCO/Polymers, Inc.	Port Arthur, TX	68	(150)	H
		182	(400)	L; Conventional
Chemplex Co.	Clinton, IA	141	(310)	L; Du Pont
		86	(190)	H; Phillips
Cities Service Co., Inc. Plastics and Special Products Div.	Lake Charles, LA	125	(275)	L; Conventional
Cities Service Co., Inc. Columbian Div.	Lake Charles, LA[1]			
Dart Indust. Inc. Chem. Group Plastic Raw Materials Sector Rexene Polymers Co.	Odessa, TX	297	(380)	L; Conventional; jointly owned with El Paso Products Co.
	Bayport, TX[2]			
Dow Chem. U.S.A.	Freeport, TX	50	(110)	H
		300	(660)	L
	Plaquemine, LA[3]	79	(175)	H; Conventional
		163	(360)	L
E. I. du Pont de Nemours & Co., Inc. Plastics Products and Resins Dept.	Orange, TX	211	(465)	L; Du Pont
		104	(230)	H
	Victoria, TX[4]	109	(240)	L; Conventional

Table C-40 (Continued). POLYETHYLENE RESIN PRODUCERS[16]

Company	Location	Capacity[15] Gg(10^6 lbs)		
Eastman Kodak Co. Eastman Chem. Products, Inc., subsid. Texas Eastman Co., div.	Longview, TX	114	(250)	L; Conventional; PE emulsions
El Paso Natural Gas El Paso Products Co., subsid.	Bayport, TX[5]			
Exxon Corp. Exxon Chem. Co., div. Exxon Chem. Co. U.S.A.	Baton Rouge, LA[6]	200	(440)	L; Rexall
Gulf Oil Corp. Gulf Oil Chems. Co., div. Plastics Div.	Cedar Bayou, TX[7]	123	(270)	L; Conventional
	Orange, TX[8]	136	(300)	L
		109	(240)	H
Mobil Oil Corp. Mobil Chem Co. div. Chem. Coatings Div.	Beaumont, TX[9]			
National Distillers and Chem. Corp. Chems. Div. U.S. Indust. Chems. Co. div.	Deer Park, TX[10]	159	(350)	L
	Tuscola, IL	68	(150)	L; Conventional
National Petro Chems. Corp.	La Porte, TX[11]	159	(350)	H; Phillips; jointly owned with Owens-Illinois, Inc.
Northern Natural Gas Co. Northern Petrochem. Co., subsid. Polymers Div.	Morris, IL[12]	279	(615)	L
Phillips Petroleum Co. Plastics Div.	Pasadena, TX	250	(550)	Phillips; includes 140 million pounds of capacity that can be used for L.

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Table C-40 (Continued). POLYETHYLENE RESIN PRODUCERS[16]

Company	Location	Capacity[15] Gg(10^6 lbs)
Pressure Chem. Co.	Pittsburgh, PA	n.a.
Soltex Polymer Corp.	Deer Park, TX	200 (440) H; Phillips
Standard Oil Co. (Indiana) Amoco Chems. Corp., subsid.	Chocolate Bayou, TX[13]	68 (150) H
Union Carbide Corp. Chems. and Plastics Div.	Seadrift, TX[14]	154 (340) L; Phillips 154 (340) H
	Taft, LA	n.a.
	Texas City, TX	125 (275) L; Conventional
	Torrance, CA	75 (165) L
Union Carbide Caribe, Inc., subsid.	Penuelas, PR	141 (310) L
	TOTAL	4500 (9911)

Notes: H - high density, low pressure

L - low density, high pressure

High density: Specific gravity over 0.940

Medium density: Specific gravity 0.926 to 0.940 (medium density material is usually in low density)

Low density: Specific gravity 0.925 and lower

In certain instances high density polyethylene capacity could be converted to polypropylene capacity. Process included under remarks.

[1] An expansion is under construction which will increase polyethylene resins capacity from 275 million pounds to 350 million pounds per year; completion was scheduled for March, 1976.

[2] A new 150 million pounds-per-year low density polyethylene resins plant is planned; construction will begin the third quarter of 1976; completion is scheduled for early 1978.

[3] An expansion is planned which will increase high density polyethylene resin capacity to 250 million pounds per year; completion is scheduled for early 1977.

[4] A new 225 million pounds-per-year high density polyethylene resins plant came on stream in late 1975.

[5] A new 150 million pound-per-year low density polyethylene plant is planned; construction will begin the third quarter of 1976; completion is scheduled for early 1978.

Table C-40 (Continued). POLYETHYLENE RESIN PRODUCERS[16]

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[6] An expansion is planned which will increase low density polyethylene resins capacity by 220 million pounds to a total of 660 million pounds per year. Completion is scheduled for mid-1977.

[7] A 280 million pound per year expansion of low density polyethylene resins capacity is under construction; completion is scheduled for mid-1977.

[8] Foster-Wheeler Energy Corp. has been awarded the contract to build a new 240 million pound-per-year high density polyethylene resins plant; completion is scheduled for mid-1977.

[9] Sterns Roger will construct the new 290 million pound-per-year low density polyethylene resins plant which is planned. Construction was to begin late 1975 with completion scheduled by late 1977. Output will be used captively.

[10] An expansion is planned which will increase low density polyethylene resins capacity from 350 million pounds to a total of 550 million pounds per year; completion is scheduled for mid-1978.

[11] H.B. Zachary Co. has been awarded the contract to build a new unit which will increase high density polyethylene resins capacity by 150 million pounds per year; completion is scheduled for early 1977.

[12] A 25 million pound-per-year expansion of polyethylene resins capacity is under construction; completion is scheduled for 1976.

[13] A 300 million pound-per-year expansion of high density polyethylene resins capacity is planned; completion is scheduled for 1976.

[14] A 400 million pound-per-year expansion of low density polyethylene resins capacity is planned; completion is scheduled for mid-1976.

[15] On stream as of January 1, 1976.

[16] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually.

Source: Directory of Chemical Producers, 1976.

Table C-41. POLYIMIDE RESIN PRODUCERS[2]

Company	Location	Type	Capacity[1] Gg(10^6 lbs)
E. I. du Pont de Nemours & Co., Inc. Plastics Products and Resins Dept.	Newark,DE	Polyimide	
Gen. Electric Co. Chem. and Metallurgical Div. Laminated and Insulating Materials Business Dept.	Schenectady, NY	Poly(ester-imide)	
Monsanto Co. Monsanto Polymers & Petrochems. Co.	Springfield, MA	Polyimide	
Standard Oil Co. (Indiana) Amoco Chems. Corp., subsid.	Joliet, IL	Polyamide-imide	
The Upjohn Co. Polymer Chems. Div.	La Porte, TX	Polyimide	

[1] On stream as of January 1, 1976.

[2] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually.

Source: Directory of Chemcial Producers, 1976

Table C-42. POLYPHENYLENE OXIDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10⁶ lbs)
Gen. Electric Co. Plastics Business Div. Engineering Plastics Product Dept.	Selkirk, NY	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976

Table C-43. POLYPHENYLENE SULFIDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10⁶ lbs)
Phillips Petroleum Co. Petrochem and Supply Div.	Phillips, TX	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976

Table C-44. POLYPROPYLENE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)	
Dart Indust. Inc. Chem. Group Plastic Raw Materials Sector Rexene Polymers Co.	Bayport, TX[3]		
	Odessa, TX[4]	64 (140)	Captive
Diamond Shamrock Corp. Diamond Shamrock Chem. Co. Plastics Div.	La Porte, TX	73 (160)	Merchant
Eastman Kodak Co. Eastman Chem. Products, Inc., subsid. Texas Eastman Co., div.	Longview, TX[5]	64 (140)	Captive
Exxon Corp. Exxon Chem. Co., div. Exxon Chem. Co. U.S.A.	Baytown, TX[6]	191 (420)	Captive
Gulf Oil Corp. Gulf Oil Chems. Co., div. Petrochemicals Div.	Cedar Bayou, TX[7]		
Hercules Inc. Polymers Dept.	Bayport, TX	181 (400)	Merchant
	Lake Charles, LA	318 (700)	Merchant
Northern Natural Gas Co. Northern Petrochem Co., subsid. Polymers Div.	Morris, IL[8]		
Novamont Corp.	Kenova, WV[9]	73 (160)	Merchant
	La Porte, TX[10]		
Phillips Petroleum Co. Plastics Div.	Pasadena, TX	45 (100)	Captive
Shell Chem. Co. Base Chems.	Norco, LA[11]		
Polymers and Detergent Products	Woodbury, NJ	127 (280)	Merchant
Standard Oil Co. (Indiana) Amoco Chems. Corp., subsid.	Chocolate Bayou, TX	114 (250)	Captive
	New Castle, DE	114 (250)	Merchant
	TOTAL	136 (3000)	

Table C-44 (Continued). POLYPROPYLENE RESIN PRODUCERS[2]

Note: In certain instances polypropylene capacity could be converted to high-density polyethylene capacity.

[1] On stream as of January 1, 1976.

[2] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually.

[3] A new 150 million pound-per-year polypropylene resins plant is under construction; completion is scheduled for mid-1976.

[4] A 10 million pound-per-year expansion of polypropylene resins capacity is planned; completion is scheduled for 1976.

[5] An expansion of propylene resins capacity is planned.

[6] An expansion is being considered which would increase capacity from 420 million pounds to a total of 750 million pounds per year.

[7] Arthur G. McKee & Co. has been awarded a contract to build a new 400 million pound per year polypropylene resins plant; completion of the 100-million dollar project is scheduled for mid-1978.

[8] A new 200 million pound-per-year polypropylene resins plant is planned. It will utilize gas-phase polymerization technology licensed from Germany's BASF AG; completion is scheduled for mid-1978.

[9] An expansion of polypropylene resins to 195 million pounds per year is planned; completion is scheduled for late 1976.

[10] A new 200 million pound-per-year polypropylene resins plant is planned; completion is scheduled for late 1977.

[11] A new 150 million pound-per-year polypropylene resins plant is planned; completion is scheduled for late 1977. A second polypropylene resins plant is under construction; completion of the 150 million pound-per-year plant is scheduled for early 1978.

Source: Directory of Chemical Producers, 1976.

Table C-45. POLYSTYRENE RESIN PRODUCERS[2]

(Straight end rubber-modified)(May include certain styrene copolymer resins and elastomers)

Company	Location	Capacity[1] Gg(10^6 lbs)		
A & E Plastik Pak Co., Inc. A & E Plastics Div.	City of Industry, CA	14	(30)	Captive Use
American Petrofina, Inc. Cosden Oil & Chem. Co., subsid.	Big Spring, TX	68	(150)	Impact polystyrene: rubber modified
	Calumet City, IL	123	(270)	
ARCO/Polymers, Inc.	Beaver Valley, PA	200	(440)	
BASF Wyandotte Corp. Colors and Chems. Group	Jamesburg, NJ (Styropar®)	50	(110)	
Beatrice Foods Co. Beatrice Chem. Div. Polyvinyl Chem. Indust. Div.	Wilmington, MA	n.a.		
Borden Inc. Borden Chem. Div. Thermoplastic Products	Bainbridge, NY	n.a.		Polystyrene emulsion
	Compton, CA	n.a.		Polystyrene emulsion
	Demopolis, AL	n.a.		Polystyrene emulsion
	Illiopolis, IL	n.a.		Polystyrene emulsion
	Leominster, MA	n.a.		Polystyrene emulsion
Dart Indust. Inc. Chem. Group Plastic Raw Materials Sector Rexene Polymers Co.	Holyoke, MA	25	(55)	
	Joliet, IL	18	(40)	
	Ludlow, MA	5	(10)	
	Santa Ana, CA	16	(35)	
Dow Chem. U.S.A.	Allyn's Point, CT	54	(120)	Polystyrene foam
	Gales Ferry, CT	75	(165)	Polystyrene foam
	Ironton, OH[3]	125	(275)	Polystyrene foam
	Joliet, IL[4]			
	Magnolia, AR	n.a.		Polystyrene foam
	Midland, MI	125	(275)	Polystyrene foam
	Pevely, MO	5	(10)	Polystyrene foam
	Torrance, CA	86	(190)	Polystyrene foam

Table C-45 (Continued). POLYSTYRENE RESIN PRODUCERS[2]
(Straight end rubber-modified)(May include certain styrene copolymer resins and elastomers

Company	Location	Capacity[1] Gg(10^6 lbs)		
Foster Grant Co., Inc.	Chesapeake, VA	68	(150)	
	Leominster, MA	55	(120)	Polystyrene foam
	Peru, IL	109	(240)	Polystyrene foam
Carl Gordon Indust., Inc.	Worcester, MA[8]	n.a.		
Gordon Chem. Co. Div.	Oxford, MA	n.a.		
Hammond Plastics Div.	Oxford, MA	14	(30)	
	Worcester, MA	23	(50)	
Hercules Inc. Organics Dept.	Clairton, PA	n.a.		Styrene resins, modified; styrene copolymers
Monsanto Co. Monsanto Polymers & Petrochems. Co.	Addyston, OH[5]	295	(650)	
	Decatur, AL	45	(100)	
	Long Beach, CA	23	(50)	
	Springfield, MA	n.a.		Capacity shared with Addyston, Ohio, plant
Morton-Norwich Ptoducts, Inc. Morton Chem. Co., div.	Ringwood, IL	n.a.		Polystyrene latex
Polysar Plastics Inc. D.C. Div., Polystyrene Plant	Forest City, NC	14	(30)	Polystyrene resin; captive use
Pressure Chem. Co.	Pittsburgh, PA	n.a.		
Purex Corp.	Bristol, PA	n.a.		Polystyrene latex
	Carson, CA	n.a.		Polystyrene latex
Reichhold Chems., Inc.	Azusa, CA	n.a.		Styrenated resins
	Detroit, MI	n.a.		Styrenated resins
	Elizabeth, NJ	n.a.		Styrenated resins
The Richardson Co. Plastics Group Polymeric Systems Div.	Channelview, TX	18	(40)	
	Madison, CT	n.a.		
	West Haven, CT	23	(50)	

Table C-45 (Continued). POLYSTYRENE RESIN PRODUCERS[2]

(Straight end rubber-modified)(May include certain styrene copolymer resins and elastomers)

Company	Location	Capacity[1] Gg(10^6 lbs)
Shell Chem. Co. Polymers and Detergent Products	Belpre, OH[6]	68 (150)
Solar Chem. Corp.	Leominster, MA	57 (125)
A. E. Staley Mfg. Co. Staley Chem. Div.	Kearny, NJ	n.a.
	Lemond, IL	n.a.
Standard Oil Co. (Indiana) Amoco Chems. Corp., subsid.	Joliet, IL	91 (200)
	Medina, OH	20 (45)
	Torrance, CA	16 (35)
	Willow Springs, IL	23 (50)
Sterling Plastics Corp.	Orange, CA	n.a.
Eastern Sterling Plastics Co.	Windsor, NJ[7]	23 (50)
Sybron Corp. Ionac Chem. Co., div.	Birmingham, NJ	n.a.
Jersey State Chem. Co., div.	Haledon, NJ	n.a.
Texas Chem. & Plastics Corp.	Long Beach, CA	23 (50)
Union Carbide Corp. Chems. and Plastics Div.	Bound Brook, NJ	58 (125)
U.S. Indust. Inc. E. Helman Co., div.	Copley, OH	39 (85)
United States Steel Corp. USS Chems., div.	Haverhill, OH	127 (280)
	TOTAL	2315 (5100)

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[1] On stream as of January 1, 1976.

[2] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually.

[3] An expansion to 210 million pounds per year of polystyrene resins capacity is planned; completion is scheduled for 1978.

[4] A new polystyrene resins plant came on stream in 1975. Completion of a second unit is scheduled for mid-1976.

Table C-45 (Continued). POLYSTYRENE RESIN PRODUCERS[2]
(Straight end rubber-modified)(May include certain styrene copolymer resins and elastomers

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[5] A new multimillion dollar plant is under construction which will increase polystyrene resins capacity by 100 million pounds per year.

[6] An expansion is planned which will increase polystyrene resins capacity to > 300 million pounds per year; completion of the first phase is scheduled for 1976 and the second phase for 1977.

[7] A new plant which doubled polystyrene resins capacity to 150 million pounds per year has come on stream.

[8] Second plant.

Source: Directory of Chemical Producers, 1976.

Table C-46. POLYSULFONE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10 lbs)
Minnesota Mining and Mfg. Co. Commercial Chems. Div.	Decatur, AL	
Union Carbide Corp. Chems. and Plastics Div.	Marietta, OH	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually.

Source: Directory of Chemical Producers, 1976.

Table C-47. POLYTERPENE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Arizona Chem. Co.	Panama City, FL	
Crosby Chems., Inc.	Picayune, MS	
Hercules Inc. Organics Dept.	Clairton, PA	
Minnesota Mining and Mfg. Co. Chem. Resources Div.	Newark, NJ	
Neville Chem. Co.	Neville Island, PA	
Reichhold Chems., Inc. Newport Div.	Pensacola, FL	
Schenectady Chems., Inc.	Rotterdam Junction, NY	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually.

Source: Directory of Chemical Producers, 1976.

Table C-48. POLY(TETRAMETHYLENETEREPHTHALATE)PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Eastman Kodak Co. Eastman Chem. Products, Inc., subsid. Tennessee Eastman Co., div.	Kingsport, TN	

[1] On stream as of January 1, 1976.

[2] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually.

Source: Directory of Chemical Producers, 1976

Table C-49. POLYURETHAN FOAM PRODUCERS[2]

(The following companies react isocyanates or prepolymers with polyols to produce polyurethan foams. The list is incomplete)

Company	Location	Capacity[1] Gg(10^6 lbs)
Applied Plastics Co. Inc.	El Segundo, CA	
E.R. Carpenter Co., Inc.	Conover, NC	
	La Mirada, CA	
	Richmond, VA	
	Russellville, KY	
	Temple, TX	
Chase Chem. Corp.	Pittsburgh, PA	
Cook Paint & Varnish Co.	North Kansas City, MO	
Dow Chem. U.S.A.	Ironton, OH	
The Firestone Tire & Rubber Co. Firestone Foam Products, div.	Conover, NC	
	Corry, PA	
	Elkhart, IN	
	Milan, TN[3]	
	Thomasville, GA	
Gen. Latex and Chem. Corp.	Ashland, OH	
	Cambridge, MA	
	Charlotte, NC	
	Cucamonga, CA	
	Dalton, GA	
Gen. Motors Corp.	Dayton, OH	
The Gen. Tire & Rubber Co. Chemical/Plastics Div.	Marion, IN	
	Orange, CA	
The B.F. Goodrich Co. B.F. Goodrich Gen. Products Co., div.	Akron, OH	
The Goodyear Tire & Rubber Co. Chem. Div.	Bakersfield, CA	
	Logan, OH	
	Luckey, OH	

Table C-49 (Continued). POLYURETHAN FOAM PRODUCERS[2]

(The following companies react isocyanates or prepolymers with polyols to produce polyurethan foams. The list is incomplete.)

Company	Location	Capacity[1] Gg(10^6 lbs)
Kewanee Indust., Inc. Millmaster Onyx Corp., subsid. Apache Foam Products Co., div.	Belvidere, IL Linden, NJ	
Midwest Mfg. Corp.	Burlington, IA	
Mobay Chem. Corp. Polyurethane Div.	Santa Ana, CA	
Olin Corp. Designed Products Div.	Benicia, CA Brook Park, OH Fogelsville, PA	
Pelron Corp.	Lyons, IL	
Reeves Bros, Inc. Curon Div.	Cornelius, NC Orlando, FL	
Scott Paper Co. Foam and Container Div.	Eddystone, PA Fort Wayne, IN	
Sheller-Globe Corp.	Iowa City, IA Keokuk, IA Tupelo, MS	
Tenneco Inc. Tenneco Chems., Inc. Foam and Plastics Div.	East Rutherford, NJ Hazelton, PA	
Textron In. Indust. Product Group Burkart/Randall Div.	Cairo, IL St. Louis, MO	

Table C-49 (Continued). POLYURETHAN FOAM PRODUCERS[2]
(The following companies react isocyanates or prepolymers with polyoles to produce polyurethan foams. The list is incomplete.)

Company	Location	Capacity[1] Gg(10^6 lbs)
United Foam Corp.	Bremen, IN Compton, CA Denver, CO Franklin, NJ Hayward, CA Honolulu, HI Los Angeles, CA Portland, OR Shawnee, OK	
United Merchants & Mfgs., Inc.		
American Plastics Div.	Elkhart, IN	
Glascoat Div.	Miami, FL	
Thalco Div.	Los Angeles, CA	
The Upjohn Co.		
CRP Div.	Fairbanks, AK Torrance, CA	
Polymer Chems. Div.	La Porte, TX	
Witco Chem. Corp.		
Isocyanate Products Div.	New Castle, DE	

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[1] On stream as of January 1, 1976.

[2] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually.

[3] A 25% expansion of polyurethan foam capacity is planned; completion is scheduled for mid-1977.

Source: Directory of Chemical Producers, 1976.

Table C-50. (Miscellaneous) POLYURETHAN RESINS PRODUCERS[2]
(Adhesives, molding resins, sealants, etc.)

Company	Location	Capacity[1] Gg(10^6 lbs)
Adhesive Products Corp.	Bronx, NY	
American Cyanamid Co. Organic Chems. Div.	Charlotte, NC	
John L. Armitage & Co.	Elk Grove, IL Newark, NJ Richmond, CA	
The Carborundum Co. Polymers Venture	Niagara Falls, NY	
Degen Oil & Chem. Co.	Jersey City, NJ	
Gen. Latex and Chem. Corp.	Cucamonga, CA	
Henkel Inc. Textilana, Div.	Hawthorne, CA	
Hexcel Corp. Rezolin Div.	Chatsworth, CA	
ICI United States Inc. Plastics Div.	Bayonne, NJ	
Philip Morris, Inc. Polymer Indust., Inc. subsid. Adhesives and Liquid Coatings Div.	Springdale, CT	
Poly Resins, Inc.	Sun Valley, CA	
Seton Co. Wilmington Chem. Corp., div.	Wilmington, DE	
Witco Chem. Corp. Organics Div.	Clearing, IL	

[1] On stream as of January, 1976.

[2] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually.

Source: Directory of Chemical Producers, 1976.

Table C-51. POLYURETHAN SURFACE COATING RESIN PRODUCERS[2]

(The following are the major suppliers of urethan coating resins to the U.S. paint companies. They do not make urethan surface coatings)

Company	Location	Capacity[1] Gg(10^6 lbs)
Ashland Oil, Inc. Lehigh Valley Chem. Co., div. Resins and Plastics Div.	Newark, NJ	
BASF Wyandotte Corp. Indust. Chems. Group	Wyandotte, MI	
Diamond Shamrock Corp. Diamond Shamrock Chem. Co. Process Chems. Div.	Harrison, NJ	
Gen. Latex and Chem. Corp.	Ashland, OH Cambridge, MA Cucamonga, CA	
The B.F. Goodrich Co. B.F. Goodrich Chem. Co., div.	Avon Lake, OH	
Internat'l Minerals & Chem. Corp. Chem. Group Commercial Solvents Corp., subsid. McWhorter Chems. Co. Div.	Carpentersville, IL	
Jones-Blair Co.	Dallas, TX	
Mobay Chem. Corp. Plastics + Coatings Div.	Cedar Bayou, TX New Martinsville, WV	
Northeastern Labs. Co., Inc.	Melville, NY	
Occidental Petroleum Corp. Hooker Chem. Corp., subsid. RUCO, subsid.	Hicksville, NY	

Table C-51 (Continued). POLYURETHAN SURFACE COATING RESIN PRODUCERS[2]

(The following are the major suppliers of urethan coating resins to the U.S. paint companies. They do not make urethan surface coatings.)

Company	Location	Capacity[1] Gg(10^6 lbs)
Reichhold Chems., Inc.	Azusa, CA Carteret, NJ Detroit, MI Elizabeth, NJ Houston, TX South San Francisco, CA Tacoma, WA	
H. H. Robertson Co. Freeman Chem. Corp., subsid.	Chatham, VA Saukville, WI	
Synres Chem. Corp.	Kenilworth, NJ	
Textron Inc. Indust. Product Group Spencer Kellogg Div.	Bellevue, OH	
Union Carbide Corp. Chems. and Plastics Div.	Institute and South Charleston, WV	

[1] On stream as of January 1, 1976.

[2] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually.

Source: Directory of Chemical Producers, 1976.

Table C-52. POLYURETHAN SURFACE COATING RESINS PRODUCERS[2]

(The following companies make urethan resins and urethan surface coatings)

Company	Location	Capacity[1] Gg(10^6 lbs)
ADCO Chem. Co., Inc.	Newark NJ	
American Can Co. M&T Chems. Inc., subsid. Furane Plastics, Inc., subsid.	Los Angeles, CA	
Ashland Oil., Inc. Lehigh Valley Chem. Co., div. Resins and Plastics Div.	Los Angeles, CA	
Ball Chem. Co. Resin Div.	Glenshaw, PA	
Beatrice Foods Co. Beatrice Chem. Div.		
Permuthane Div.	Peabody, MA	
Polyvinyl Chem. Indust. Div.	Wilmington, MA	
Stahl Finish Div.	Peabody, MA	
Celanese Corp. Celanese Coatings and Specialty Chems. Co., subsid. Celanese Resins Div.	Louisville, KY	
Chem. Coatings & Engineering Co., Inc.	Media, PA	
Chem. Processors, Inc.	Seattle, WA	
Conchemco Inc. Kansas City Operations	Kansas City, MO	
De Soto, Inc.	Berkeley, CA Chicago Heights, IL Garland, TX	
The Dexter Corp. Midland Div.	Cleveland, OH Hayward, CA Rocky Hill, CT Waukegan, IL	

Table C-52 (Continued). POLYURETHAN SURFACE COATING RESINS PRODUCERS[2]
(The following companies make urethan resins and urethan surface coatings)

Company	Location	Capacity[1] Gg(10^6 lbs)
E. I. du Pont de Nemours & Co., Inc. Fabrics and Finishes Dept.	Toledo, OH	
Elliott Paint & Varnish Co. Armstrong Paint Co., div.	Chicago, IL	
ELT Inc. Baltimore Paint & Chem. Corp., subsid.	Baltimore, MD	
The Flamemaster Corp. Chem-Seal Corp., div.	Sun Valley, CA	
Ford Motor Co. Gen. Products Div.	Mt. Clemens, MI	
The P. D. George Co.	St. Louis, MO	
Grow Chem. Corp. U.S. Paint, Lacquer and Chem. Co., subsid.	St. Louis, MO	
Indpol	Cucamonga, CA	
Inmont Corp.	Grand Rapids, MI Morganton, NC	
Insilco Corp. The Enterprise Companies, div.	Wheeling, IL	
Isochem Resins Co.	Lincoln, RI	
Kohler-McLister Paint Co.	Denver, CO	
Lord Corp. Hughson Chems. Div.	Saegertown, PA	
Mameco Internat'l	Cleveland, OH	
Marcor Inc. Montgomery Ward & Co., subsid. Standard T. Chem. Co., Inc., subsid.	Chicago Heights, IL	

Table C-52 (Continued). POLYURETHAN SURFACE COATING RESINS PRODUCERS[2]
(The following companies make urethan resins and urethan surface coatings)

Company	Location	Capacity[1] Gg(10^6 lbs)
McCloskey Varnish Co.	Los Angeles, CA Philadelphia, PA Portland, OR	
Midwest Mfg. Corp.	Burlington, IA	
N L Indust., Inc. Indust. Chems. Div.	Philadelphia, PA	
Norris Paint & Varnish Co.	Salem, OR	
Olin Corp. Designed Products Div.	Rochester, NY	
C. J. Osborn Chems. Inc.	Pennsauken, NJ	
Polychrome Corp Cellomer Corp., subsid.	Newark, NJ	
Poly Resins, Inc.	Sun Valley, CA	
Pratt & Lambert, Inc.	Buffalo, NY	
K. J. Quinn & Co., Inc. Polymer Div.	Malden, MA Seabrook, NH	
Schenectady Chems., Inc.	Rotterdam Junction, NY Schenectady, NY	
SCM Corp. Glidden-Durkee Div. Coatings and Resins Group	Chicago, IL Cleveland, OH Reading, PA San Francisco, CA	
Seton Co. Wilmington Chem. Corp., div.	Wilmington, DE	
Syncon Resins Inc. Farnow, Inc., div.	South Kearny, NJ	
Textron Inc. Indust. Product Group Kelly-Pickering Chems. Dept.	San Carlos, CA	

Table C-52 (Continued). POLYURETHAN SURFACE COATING RESINS PRODUCERS[2]

(The following companies make urethan resins and urethan surface coatings)

Company	Location	Capacity[1] Gg(10^6 lbs)
Trancoa Chem. Corp.	Reading, MA	
Valspar Corp. Mid west Synthetics Co., div.	Rockford, IL	
Westinghouse Electric Corp. Insulating Materials Div.	West Mifflin, PA	
Witco Chem. Corp. Organics Div.	Clearing, IL	
Woburn Chem. Corp.	Kearny, NJ	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-53. POLY(VINYL ACETATE) RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
ADCO Chem. Co., Inc.	Newark, NJ	
Air Products and Chems., Inc.		
Polymer Chems. Div.	Calvert City, KY	
	City of Industry, CA	
	Cleveland, OH	
	Elkton, MD	
AZS Corp.		
AZS Chem. Co. Div.	Atlanta, GA	
Bennett's	Salt Lake City, UT	
Borden Inc.		
Borden Chem. Div.		
Adhesives and Chems. Div.-East	Bainbridge, NY	
	Demopolis, AL	
Thermoplastic Products	Bainbridge, NY	
	Compton, CA	
	Demopolis, AL	
	Illiopolis, IL	
	Leominster, MA	
Celanese Corp.		
Celanese Coatings and Specialty Chems. Co., subsid.		
Celanese Resins Div.	Belvidere, NJ	
	Bridgeview, IL	
	Charlotte, NC	
	Los Angeles, CA	
	Louisville, KY	
	Newark, CA	
Wica Chems. Div.	Charlotte, NC	
Chem. Processors, Inc.	Seattle, WA	
Ciba-Geigy Corp.		
Dyestuffs and Chems. Div.		
Chas. S. Tanner Co. subsid.	Greenville, SC	
Colloids, Inc.		
Cellate, Inc., subsid.	Franklin, NJ	
Conchemco Inc.		
Baltimore Operations	Baltimore, MD	
Kansas City Operations	Kansas City, MO	

Table C-53 (Continued). POLY(VINYL ACETATE) RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Dan River, Inc.	Danville, VA	
De Soto, Inc.	Berkeley, CA	
	Chicago Heights, IL	
	Garland, TX	
Diamond Shamrock Corp. Diamond Shamrock Chem. Co. Process Chems. Div.	Richmond, CA	
ELT Inc. Baltimore Paint & Chem. Corp., subsid.	Baltimore, MD	
Emkay Chem. Co.	Elizabeth, NJ	
Foy-Johnston, Inc.	Cincinnati, OH	
Franklin Chem. Co.	Columbus, OH	
H. B. Fuller Co. Paisley Products Div.	Chicago, IL	
	Edison, NJ	
	Forest Park, GA	
Polymer Div.	Atlanta, GA	
	Blue Ash, OH	
Gen. Latex and Chem. Corp.	Ashland, OH	
	Cambridge, MA	
	Charlotte, NC	
	Dalton, GA	
W. R. Grace & Co. Indust. Chems. Group Dewey and Almy Chem. Div.	Owensboro, KY	
	South Acton, MA	
Great Northern Paint & Chem. Corp.	East Paterson, NJ	
	Lodi, NJ	
Grow Chem. Corp. Boysen Paint Co., subsid.	Oakland, CA	

Table C-53 (Continued). POLY(VINYL ACETATE) RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Gulf Oil Corp. Gulf Oil Chems. Co., div. Indust. and Specialty Chems. Div.	Lansdale, PA	
Hanna Chem. Coatings Corp.	Columbus, OH	
Hanna Chem. Coatings Co., subsid.	Birmingham, AL	
Hart Products Corp.	Jersey City, NJ	
H & N Chem. Co.	Totowa, NJ	
Insilco Corp. Sinclair Paint Co., div.	Los Angeles, CA	
Jones-Blair Co.	Dallas, TX	
Kelly-Moore Paint Co.	San Carlos, CA	
Kewanee Indust., Inc. Millmaster Onyx Corp., subsid. Refined-Onyx Div.	Lyndhurst, NJ	
Kohler-McLister Paint Co.	Denver, CO	
McCloskey Varnish Co.	Los Angeles, CA Philadelphia, PA Portland, OR	
Monsanto Co. Monsanto Ploymers & Petrochems. Co.	Springfield, MA	
Benjamin Moore & Co.	Los Angeles, CA Melrose Park, IL Newark, NJ St. Louis, MO	
Napko Corp.	Houston, TX	
National Casein of California	Santa Ana, CA	

Table C-53 (Continued). POLY(VINYL ACETATE) RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
National Casein Co.	Chicago, IL	
National Starch and Chem. Corp.	Meredosia, IL Plainfield, NJ	
Norris Paint & Varnish Co.	Salem, OR	
Northeastern Labs Co., Inc.	Melville, NY	
The O'Brien Corp.	Baltimore, MD South Bend, IN	
Onyx Oils & Resins, Inc.	Brooker, FL	
Philip Morris, Inc. Polymer Indust., Inc. subsid. Adhesives and Liquid Coatings Div.	Springdale, CT	
Textile Chems. Div.	Greenville, SC	
Raffi and Swanson, Inc. Polymeric Resins Div.	Wilmington, MA	
Reichhold Chems., Inc.	Azusa, CA Charlotte, NC Kansas City, KS Morris, IL South San Francisco, CA Tacoma, WA	
Scholler Bros. Inc.	Elwood, NJ	
SCM Corp. Glidden-Durkee Div. Coatings and Resins Group	Chicago, IL Cleveland, OH Huron, OH Reading, PA San Francisco, CA	
The Sherwin-Williams Co.	Chicago, Il	
Southeastern Adhesives Co.	Lenoir, NC	

Table C-53 (Continued). POLY(VINYL ACETATE) RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Standard Brands, Inc. Standard Brands Chem. Indust., Inc., div. Tylac Chems., div.	Cheswold, DE	
Sybron Corp. Jersey State Chem. Co., div.	Haledon, NJ	
Syncon Resins Inc. Farnow, Inc., div.	South Kearny, NJ	
Union Carbide Corp. Chems. and Plastics Div.	Institute and South Charleston, WV	
Union Oil Co. of California AMSCO Div.	Charlotte, NC La Mirada, CA	
Yenkin-Majestic Paint Corp. Ohio Polychemicals Co., div.	Columbus, OH	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-54. POLY(VINYL ALCOHOL) RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Air Products and Chems. , Inc. Polymer Chems. Div.	Calvert City, KY	18 (40)
Borden Inc. Borden Chem. Div. Thermoplastic Products	Leominster, MA	2 (8)[4]
E. I. du Pont de Nemours & Co., Inc. Plastics Products and Resins Dept.	La Porte, TX[3]	45 (100)
Monsanto Co. Monsanto Polymers & Petrochems. Co.	Springfield, MA	14 (30)
	TOTAL	79 (178)

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

[3] An expansion which will increase poly(vinyl alcohol) resins capacity to 125 million pounds per year is planned; completion is scheduled for 1977

[4] On stand-by

Source: Directory of Chemical Producers, 1976.

Table C-55. POLY(VINYL BUTYRAL) RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
E. I. du Pont de Nemours & Co., Inc. Plastics Products and Resins Dept.	Parkersburg, WV	
Monsanto Co. Monsanto Polymers & Petrochems. Co.	Springfield, MA[3] Trenton, MI	
Union Carbide Corp. Chems. and Plastics Div.	Charleston, WV	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually

[3] A new multimillion dollar poly(vinyl butyral) resins plant is planned which will increase company's capacity by 25%; completion is scheduled for late 1976.

Source: Directory of Chemical Producers, 1976.

Table C-56. POLY(VINYL CHLORIDE) RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Air Products and Chems., Inc. Plastics Div.	Calvert City, KY[3]	68 (150)
	Pensacola, FL[4]	28 (50)
Atlantic Tubing & Rubber Co.	Cranston, RI	28 (50)
Borden, Inc. Borden Chem. Div. Thermoplastic Products	Illiopolis, IL	182 (400)
	Leominster, MA	66 (145)
Certain-Teed Products Corp.	Lake Charles, LA	490
Continental Oil Co. Conoco Chems. Div.	Aberdeen, MS[5]	222 (290)
	Oklahoma City, OK	107 (235)
Diamond Shamrock Corp. Diamond Shamrock Chem. Co. Plastics Div.	Deer Park, TX	213 (470)
	Delaware City, DE	45 (100)
Ethyl Corp.	Baton Rouge, LA	82 (180)
The Firestone Tire & Rubber Co. Firestone Plastics Co., div.	Perryville, MD	204 (450)
	Pottstown, PA	
The Gen. Tire & Rubber Co. Chemical/Plastics Div.	Ashtabula, OH	57 (125)
	Point Pleasant, WV	27 (60)
Georgia-Pacific Corp. Chem. Div.	Plaquemine, LA	100 (220)
The B. F. Goodrich Co. B. F. Goodrich Chem. Co., div.	Avon Lake, OH	73 (160)
	Henry, IL	73 (160)
	Long Beach, CA	73 (160)
	Louisville, KY	163 (360)
	Pedricktown, NJ	77 (170)

Table C-56 (Continued). POLYVINYL CHLORIDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
The Goodyear Tire & Rubber Co. Chem. Div.	Niagara Falls, NY[6]	23 (50)
	Plaquemine, LA	90 (200)
Great American Chem. Corp.	Fitchburg, MA	18 (40)
Keysor-Century Corp.	Saugus, CA	34 (75)
National Starch and Chem. Corp.	Meredosia, IL	4 (10)
The Pantasote Co. of New York, Inc. Eleonora Chem. Div.	Passaic, NJ	27 (60)
	Point Pleasant, WV	27 (60)
Rhodia, Inc.	Brazosport, TX	2 (7)
Rico Chems. Corp.	Guayanilla, PR	73 (160)
ROBINTECH Inc.	Painesville, OH	114 (250)
SHINTECH Inc.	Freeport, TX[7,9]	100 (220)
Stauffer Chem. Co. Plastics Div. Polymers East	Delaware City, DE[8]	77 (170)
Polymers West	Carson, CA	66 (145)
Tenneco Inc. Tenneco Chems., Inc. Organics and Polymers Div.	Burlington, MJ	70 (155)
	Flemington, NJ	36 (80)
	Pasadena, TX	109 (240)
Union Carbide Corp. Chems. and Plastics Div.	Institute and South Charleston, WV	159 (350)
	Texas City, TX	
	TOTAL	3129 (6892)

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[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually

[3] A 200 to 300 million pound per year expansion of poly(vinyl chloride) resins capacity is planned

Table C-56 (Continued). POLYVINYL CHLORIDE RESIN PRODUCERS[2]

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[4] An expansion of poly(vinyl chloride) resins capacity to 150 million pounds per year is planned; completion is scheduled for 1977.

[5] An expansion of poly(vinyl chloride) resins capacity to 500 million pounds per year is planned.

[6] The 650 thousand-dollar expansion which will increase poly(vinyl chloride) resins capacity by 25 million pounds per year to a total of 75 million pounds per year is planned; completion is scheduled for late 1976.

[7] An expansion which will increase poly(vinyl chloride) resins capacity to 370 million pounds per year is planned; completion is scheduled for January, 1976.

[8] An expansion which has increased poly(vinyl chloride) resins capacity to 185 million pounds per year has come on stream. An additional expansion which will increase poly(vinyl chloride) resins capacity to 245 million pounds per year is scheduled for late 1976.

[9] Captive use.

Source: Directory of Chemical Producers, 1976.

Table C-57. POLY(VINYL CHLORIDE)-ACETATE COPOLYMER RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg (10^6 lbs)
Air Products And Chems., Inc. Plastics Div.	Calvert City, KY	
Atlantic Tubing & Rubber Co.	Cranston, RI	
Borden Inc. Borden Chem. Div. Thermoplastic Products	Bainbridge, NY	
	Compton, CA	
	Demopolis, AL	
	Illiopolis, IL	
	Leominster, MA	
The Firestone Tire & Rubber Co. Firestone Plastics Co., div.	Pottstown, PA	
The B. F. Goodrich Co. B. F. Goodrich Chem. Co., div.	Avon Lake, OH	
	Louisville, KY	
National Starch and Chem. Corp.	Meredosia, IL	
Occidental Petroleum Corp. Hooker Chem. Corp., subsid. RUCO, subsid.	Hicksville, NY	
The Pantasote Co. of New York, Inc. Eleonora Chem. Div.	Passaic, NJ	
	Point Pleasant, WV	
Stauffer Chem. Co. Plastics Div. Polymers East	Delaware City, DE	
Polymers West	Carson, CA.	
Tenneco Inc. Tenneco Chems., Inc. Organics and Polymers Div.	Burlington, NJ	
	Flemington, NJ	

Table C-57 (Continued). POLY(VINYL CHLORIDE)-ACETATE COPOLYMER RESIN PROUDCERS

Company	Location	Capacity[1] Gg(10^6 lbs)
Union Carbide Corp. Chems. and Plastics Div.	Institute and South Charleston, WV Texas City, TX	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-58. POLY(VINYL CHLORIDE)-PROPYLENE COPOLYMER RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg (10^6 lb)
Air Products and Chems., Inc. Plastics Div.	Calvert City, KY	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually.

Source: Directory of Chemical Producers, 1976.

Table C-59. POLY(VINYL CHLORIDE)-VINYLIDENE CHLORIDE COPOLYMER RESINS PRODUCERS[2]

Company	Location	Capacity[1] Gg (10^6 lbs)
BASF Wyandotte Corp. Colors and Chems. Group	Kearny, NJ	
Borden, Inc. Borden Chem. Div. Thermoplastic Products	Bainbridge, NY	
	Compton, CA	
	Demopolis, AL	
	Illiopolis, IL	
	Leominster, MA	
Dow Chem. U.S.A.	Midland, MI	
The B. F. Goodrich Co. B. F. Goodrich Chem. Co. Div.	Louisville, KY	
W. R. Grace & Co. Indust. Chems. Group Dewey and Almy Chem. Div.	Owensboro, KY	
	South Acton, MA	
Morton-Norwich Products, Inc. Morton Chem. Co., Div.	Ringwood, IL	
National Starch and Chem. Corp.	Meredosia, IL	

[1] On stream as of January 1, 1976

[2] Products considered manufacture materials in commerciably salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-60. POLY(VINYL FORMAL) RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg (10^6 lbs)
Monsanto Co. Monsanto Polymers & Petrochems. Co.	Springfield, MA	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-61. PROPYLENE-ETHYLENE COPOLYMER RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg (10^6 lbs)
Eastman Kodak Co. Eastman Chem. Products, Inc., subsid. Texas Eastman Co., div.	Longview, TX	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-62. RESCRCINOL-FORMALDEHYDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg (10^6 lbs)
Ashland Oil, Inc.		
Lehigh Valley Chem. Co., div.		
Resins and Plastics Div.	Calumet City, IL	
	Fords, NJ	
	Pensacola, FL	
Borden Inc.		
Borden Chem. Div.		
Adhesives and Chems. Div. - East	Bainbridge, NY	
	Diboll, TX	
	Fayetteville, NC	
	Sheboygan, WI	
Adhesives and Chems. Div. - West	Fremont, CA	
	Kent, WA	
	Springfield, OR	
Georgia-Pacific Corp.		
Chem. Div.	Albany, OR	
	Columbus, OH	
	Conway, NC	
	Coos Bay, OR	
	Louisville, MS	
	Lufkin, TX	
	Russellville, SC	
	Savannah, GA	
	Vienna, GA	
Koppers Co., Inc.		
Organic Materials Div.	Petrolia, PA	
National Casein of California	Santa Ana, CA	
National Casein Co.	Chicago, IL	
	Tyler, TX	
National Casein of New Jersey		
Adhesives Div.	Riverton, NJ	
Polymer Applications, Inc.	Tonawanda, NY	

Table C-62 (Continued). RESORCINOL-FORMALDEHYDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg (10^6 lbs)
Reichhold Chems., Inc.	Tacoma, WA	
Schenectady Chems., Inc.	Rotterdam Junction, NY Schenectady, NY	
Union Carbide Corp. Chems. and Plastics Div.	Bound Brook, NJ	
Univar Corp. Pacific Resins & Chems., Inc., subsid.	Portland, OR	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-63. ROSIN AND ROSIN ESTER PRODUCERS[2]

Company	Location	Capacity[1] Gg (10^6 lbs)
Arizona Chem. Co.	Panama City. FL	
Ashland Oil, Inc.		
Lehigh Valley Chem. Co., div.		
Resins and Plastics Div.	Pensacola, FL	
Conchemco Inc.		
Baltimore Operations	Baltimore, MD	
Kansas City Operations	Kansas City, MO	
Cook Paint & Varnish Co.	North Kansas City, MO	
Crosby Chems., Inc.	De Ridder, LA	
	Picayune, MS	
De Soto, Inc.	Garland, TX	
Dixie Pine Products Co., Inc.	Hattiesburg, MS	
Eastern Color & Chem. Co.	Providence, RI	
Gilman Paint & Varnish Co.	Chattanooga, TN	
Guardsman Chems., Inc.	Grand Rapids, MI	
Hercules Inc.		
Organics Dept.	Brunswick, GA	
	Burlington, NJ	
	Hattiesburg, MS	
Lawter Chems., Inc.	South Kearny, NJ	
Stresen-Reuter Div.	Bensenville, IL	
McCloskey Varnish Co.	Los Angeles, CA	
	Philadelphia, PA	
	Portland, OR	
The O'Brien Corp.	Baltimore, MD	
	South Bend, IN	
Buller-O'Brien Corp., subsid.	South San Francisco, CA	

Table C-63 (Continued). ROSIN AND ROSIN ESTER PRODUCERS[2]

Company	Location	Capacity[1] Gg (10^6 lbs)
Occidental Petroleum Corp. Hooker Chem. Corp., subsid. Hooker Chems. and Plastics Corp., subsid Durez Div.	Kenton, OH North Tonawanda, NY	
Onyx Oils & Resins, Inc.	Newark, NJ	
Reichhold Chems., Inc.	Columbia, MS Houston, TX South San Francisco, CA	
Newport Div.	Gulfport, MS	
Rohm and Haas Co.	Philadelphia, PA	
Schenectacy Chems., Inc.	Rotterdam Junction, NY Schenectady, NY	
Syncon Resins Inc. Farnow, Inc., div.	South Kearny, NJ	
Synres Chem. Corp. Shanco Plastics & Chems., subsid.	Tonawanda, NY	
Union Camp Corp. Chem. Products Div.	Valdosta, GA	
Union Carbide Corp. Chems. and Plastics Div.	Bound Brook, NJ	
Westvaco Corp. Chem. Div. Custom Chems. Dept.	Charleston Heights, SC	

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[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually.

Source: Directory of Chemical Producers, 1976.

Table C-64. SILICONE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg (10^6 lbs)
Ashland Oil, Inc. Lehigh Valley Chem. Co., div. Northwestern Refining Co., subsid.	St. Paul Park, MN	
Cargill, Inc. Chem. Products Div.	Philadelphia, PA	
The Dexter Corp. Midland Div.	Cleveland, OH Hayward, CA Rocky Hill, CT Waukegan, IL	
Dow Corning Corp.	Midland, MI	
General Electric Co. Chem. and Metallurgical Div. Silicone Products Dept.	Waterford, NY	
Isochem Resins Co.	Lincoln, RI	
Marcor Inc. Montgomery Ward & Co., subsid. Standard T Chem. Co., Inc., subsid	Chicago Heights, IL Linden, NJ	
Morris Indust. Inc. Lanson Chem. Co., div.	East St. Louis, IL	
Synres Chem. Corp.	Kenilworth, NJ	
Synthane-Taylor Corp.	Betzwood, PA	
Union Carbide Corp. Chems. and Plastics Div.	Sistersville, WV	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amount, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-65. STYRENE-ALLYL RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg (10^6 lbs)
Monsanto Co. Monsanto Polymers & Petrochems. Co.	Trenton, MI	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-66. STYRENE-BUTADIENE COPOLYMER RESIN PRODUCERS[2]

Company	Location	Type	Capacity[1] Gg (10^6 lbs)
American Synthetic Rubber Corp.	Louisville, KY	L	
ARCO/Polymers, Inc.	Beaver Valley, PA	L	
Borden, Inc. Borden Chem. Div. Thermoplastic Products	Illiopolis, IL	L	
Dart Indust. Inc. Chem. Group Plastic Raw Materials Sector Southwest Latex Corp.	Bayport, TX	L	
Dow Chem., U.S.A.	Freeport, TX	L	
	Midland, MI	L	
	Pittsburgh, CA	L	
The Firestone Tire & Rubber Co. Firestone Synthetic Rubber and Latex Co., div.	Akron, OH	L	
GAF Corp. Chem. Products	Chattanooga, TN	L	
The Gen. Tire & Rubber Co. Chemical/Plastics Div.	Mogadore, OH	L	
	Odessa, TX	L	
The B. F. Goodrich Co. B. F. Goodrich Chem. Co., div.	Louisville, KY	L	
The Goodyear Tire & Rubber Co. Chem. Div.	Akron, OH	L	
W. R. Grace & Co. Indust. Chems. Group Dewey and Almy Chem. Div.	Owensboro, KY	L	
	South Acton, MA	L	

Table C-66 (Continued). STYRENE-BUTADIENE COPOLYMER RESIN PROUDCERS[2]

Company	Location	Type	Capacity[1] Gg (10^6 lbs)
Phillips Petroleum Co. Rubber Chems. Div.	Borger, Tex.	R (solid)	
Standard Brands, Inc. Standard Brands Chem. Indust., Inc., div. Tylac Chems., div.	Cheswold, DE	L	
	Kensington, GA	L	
Union Oil Co. of California AMSCO Div.	Charlotte, NC	L	
	La Mirada, CA	L	
Uniroyal, Inc. Uniroyal Chem., div.	Scotts Bluff, LA	L	

Notes: R - Resin

L - Latex

On stream as of January 1, 1976

Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-67. STYRENE-DIVINYLBENZENE COPOLYMER RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg (10^6 lbs)
Dow Chemical, U.S.A.	Midland, MI	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

TABLE C-68. STYRENE-MALEIC ANHYDRIDE COPOLYMER RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg (10^6 lbs)
Atlantic Richfield Co. ARCO Chem. Co., div.	Channelview, TX	
Monsanto Co. Monsanto Polymers & Petrochems. Co.	Addyston, OH Everett, MA	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amount, i.e., greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-69. THERMOPLASTIC RESIN PRODUCERS[2]

Company	Location	Capacity[2] Gg(10^6 lbs)
Hastings Plastics Inc.	Santa Monica, CA	
K. J. Quinn & Co., Inc. Polymer Div.	Malden, MA Seabrook, NH	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-70. TRIAZONE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
American Cyanamid Co. Organic Chems. Div.	Charlotte, NC	
Rohm and Haas Co.	Philadelphia, PA	
Sun Chem. Corp. Chems. Group Chems. Div.	Chester, SC	
United Merchants & Mfgs., Inc. Valchem - Chem. Div.	Langley, SC	
U.S. Oil Co.	East Providence, RI	
Southern U.S. Chem. Co., Inc., subsid.	Rock Hill, SC	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-71. UREA-FORMALDEHYDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Allied Chem. Corp.		
Specialty Chems. Div.	South Point, OH	
	Toledo, OH	
American Cyanamid Co.		
Indust. Chems. and Plastics Div.	Azusa, CA	
	Wallingford, CT	
Organic Chems. Div.	Charlotte, NC	
Formica Corp., subsid.	Evandale, OH	
Apex Chem. Co., Inc.	Elizabethport, NJ	
Ashland Oil, Inc.		
Lehigh Valley Chem. Co., div.		
Resins and Plastics Div.	Calumet City, IL	
	Fords, NJ	
	Los Angeles, CA	
The Bendix Corp.		
Friction Materials Div.	Troy, NY	
Borden Inc.		
Borden Chem. Div.		
Adhesives and Chems. Div. - East	Bainbridge, NY	
	Demopolis, AL	
	Diboll, TX	
	Fayetteville, NC	
	Louisville, KY	
	Sheboygan, WI	
Adhesives and Chems. Div. - West	Fremont, CA	
	Kent, WA	
	La Grande, OR	
	Missoula, MT	
	Springfield, OR	
Brown Co.	Gorham, NH	
Cargill, Inc.		
Chem. Products Div.	Carpentersville, IL	
	Lynwood, CA	
	Philadelphia, PA	

Table C-71 (Continued). UREA-FORMALDEHYDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Celanese Corp. Celanese Coatings and Specialty Chems. Co., subsid. Celanese Resins Div.	Louisville, KY	
Wica Chems. Div.	Charlotte, NC	
Champion Internat'l Corp. U.S. Plywood Div.	Anderson, CA	
Chem. Products Corp.	Elmwood Park, NJ	
Commercial Products Co.	Hawthorne, NJ	
Cook Paint & Varnish Co.	Detroit, MI North Kansas City, MO	
Dan River, Inc.	Danville, VA	
De Soto, Inc.	Berkeley, CA Garland, TX	
Dock Resins Corp.	Linden, NJ	
Eastern Color & Chem. Co.	Providence, RI	
Emkay Chem. Co.	Elizabeth, NJ	
Georgia-Pacific Corp. Chem. Div.	Albany, OR Columbus, OH Conway, NC Coos Bay, OR Crossett, AR Louisville, MS Lufkin, TX Russellville, SC Savannah, GA Taylorsville, MS Vienna, GA	
Guardsman Chems., Inc.	Grand Rapids, MI	

Table C-71 (Continued). UREA-FORMALDEHYDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Gulf Oil Corp.		
Gulf Oil Chems. Co., div.		
Indust. and Specialty Chems. Div.	Alexandria, LA	
	High Point, NC	
	Lansdale, PA	
	Shawano, WI	
	West Memphis, AR	
Hanna Chem. Coatings Corp.	Columbus, OH	
Hanna Chem. Coatings Co., subsid.	Birmingham, AL	
Hart Products Corp.	Jersey City, NJ	
Hercules Inc.		
Organics Dept.	Chicopee, MA	
	Hattiesburg, MS	
	Milwaukee, WI	
	Portland, OR	
	Savannah, GA	
H & N Chem. Co.	Totawa, NJ	
E. F. Houghton & Co.	Philadelphia, PA	
The Ironsides Co.	Columbus, OH	
Kewanee Indust., Inc.		
Millmaster Onyx Corp., subsid.		
Refined-Onyx Div.	Lyndhurst, NJ	
Koppers Co., Inc.		
Organic Materials Div.	Bridgeville, PA	
Mobil Oil Corp.		
Mobil Chem. Co., div.		
Chem. Coatings Div.	Kankakee, IL	
Monsanto Co.		
Monsanto Polymers & Petrochems. Co.	Addyston, OH	
	Chocolate Bayou, TX	
	Eugene, OR	
	Santa Clara, CA	
	Springfield, MA	

Table C-71 (Continued). UREA-FORMALDEHYDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
National Casein of California	Santa Ana, CA	
National Casein Co.	Chicago, IL Tyler, TX	
National Casein of New Jersey Adhesives Div.	Riverton, NJ	
National Starch and Chem. Corp. Proctor Chem. Co., subsid.	Salisbury, NC	
Onyx Oils & Resins, Inc.	Brooker, FL Newark, NJ	
Owens-Corning Fiberglas Corp. Resins and Coatings Div.	Kansas City, KS	
Perstorp U.S. Inc.	Florence, MA	
Pioneer Plastics Corp. Chem. Div.	Auburn, ME	
Plastics Mfg. Co.	Dallas, TX	
PPG Indust., Inc. Coatings and Resins Div.	Circleville, OH Oak Creek, WI	
Reichhold Chems., Inc.	Andover, MA Azusa, CA Detroit, MI Houston, TX Malvern, AR Moncure, NC South San Francisco, CA Tacoma, WA Tuscaloosa, AL White City, OR	
Varcum Chem. Div.	Niagara Falls, NY	

Table C-71 (Continued). UREA-FORMALDEHYDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Reliance Universal Inc. Chem. Coatings and Resins Group	Brea, CA	
	Clinton, MS	
	High Point, NC	
	Houston, TX	
	Louisville, KY	
	Roanoke, VA	
	Salem, OR	
	Somerset, NJ	
	Sunnyvale, CA	
	Virginia Beach, VA	
	Zion, IL	
Renroh Inc.	New Bern, NC	
Riegel Textile Corp. H.I.T. Chems. Div.	Ware Shoals, SC	
Rock Hill Printing & Finishing Co.	Rock Hill, SC	
Rohm and Haas Co.	Philadelphia, PA	
Scher Brothers, Inc.	Clifton, NJ	
Scott Paper Co. Packaged Products Div.	Chester, PA	
	Everett, WA	
	Fort Edward, NY	
	Marinette, WI	
	Mobile, AL	
The Sherwin-Williams Co.	Chicago, IL	
	Cleveland, OH	
	Newark, NJ	
Skelly Oil Co. Chembond Corp., subsid.	Anadalusia, AL	
	Springfield, OR	
	Winnfield, LA	
Sou-Tex Chem. Co., Inc.	Mount Holly, NC	

Table C-71 (Continued). UREA-FORMALDEHYDE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Southeastern Adhesives Co.	Lenoir, NC	
Sun Chem. Corp. Chems. Group Chems. Div.	Chester, SC	
Sybron Corp. Jersey State Chem. Co., div.	Haledon, NJ	
United-Erie, Inc.	Erie, PA	
United Merchants & Mfgs., Inc. Valchem - Chem. Div.	Langley, SC	
U.S. Oil Co. Southern U.S. Chem. Co., Inc., subsid.	Rock Hill, SC	
Univar Corp. Pacific Resins & Chems., Inc., subsid.	Eugene, OR Newark, OH Portland, OR Richmond, CA	
USM Corp. Crown-Metro, Inc., subsid.	Greenville, SC	
Virginia Chems. Inc. Indust. Chems. Dept.	Portsmouth, VA	
Weyerhaeuser Co.	Longview, WA Marshfield, WI	
Woonsocket Color & Chem. Co.	Woonsocket, RI	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-72. VINYL 1,2-POLYBUTADIENE RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Colorado Chem. Specialties	Golden, CO	

[1]On stream as of January 1, 1976

[2]Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annuallv or more than 1,000 lbs annuallv

Source: Directory of Chemical Producers, 1976

Table C-73. 1-VINYL-2-PYRROLIDINONE-STYRENE COPOLYMER RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
GAF Corp. Chem. Products	Calvert City, KY	

[1]On stream as of January 1, 1976

[2]Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-74. VINYLTOLUENE-ACRYLIC COPOLYMER RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
The Goodyear Tire & Rubber Co. Chem. Div.	Akron, OH	

[1]On stream as of January 1, 1976

[2]Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.

Table C-75. VINYL TOLUENE COPOLYMER RESIN PRODUCERS[2]

Company	Location	Capacity[1] Gg(10^6 lbs)
Ball Chem. Co. Resin Div.	Glenshaw, PA	
Degen Oil & Chem. Co.	Jersey City, NJ	
The Goodyear Tire & Rubber Co. Chem. Div.	Akron, ON	
Hercules Inc. Organics Dept.	Clairton, PA West Elizabeth, PA	
Textron Inc. Indust. Product Group Spencer Kellogg Div.	Bellevue, OH	
Yenkin-Majestic Paint Corp. Ohio Polychemicals Co., div.	Columbus, OH	

[1] On stream as of January 1, 1976

[2] Producers considered manufacture materials in commercially salable amounts, i.e. greater than $1,000 sales annually or more than 1,000 lbs annually

Source: Directory of Chemical Producers, 1976.